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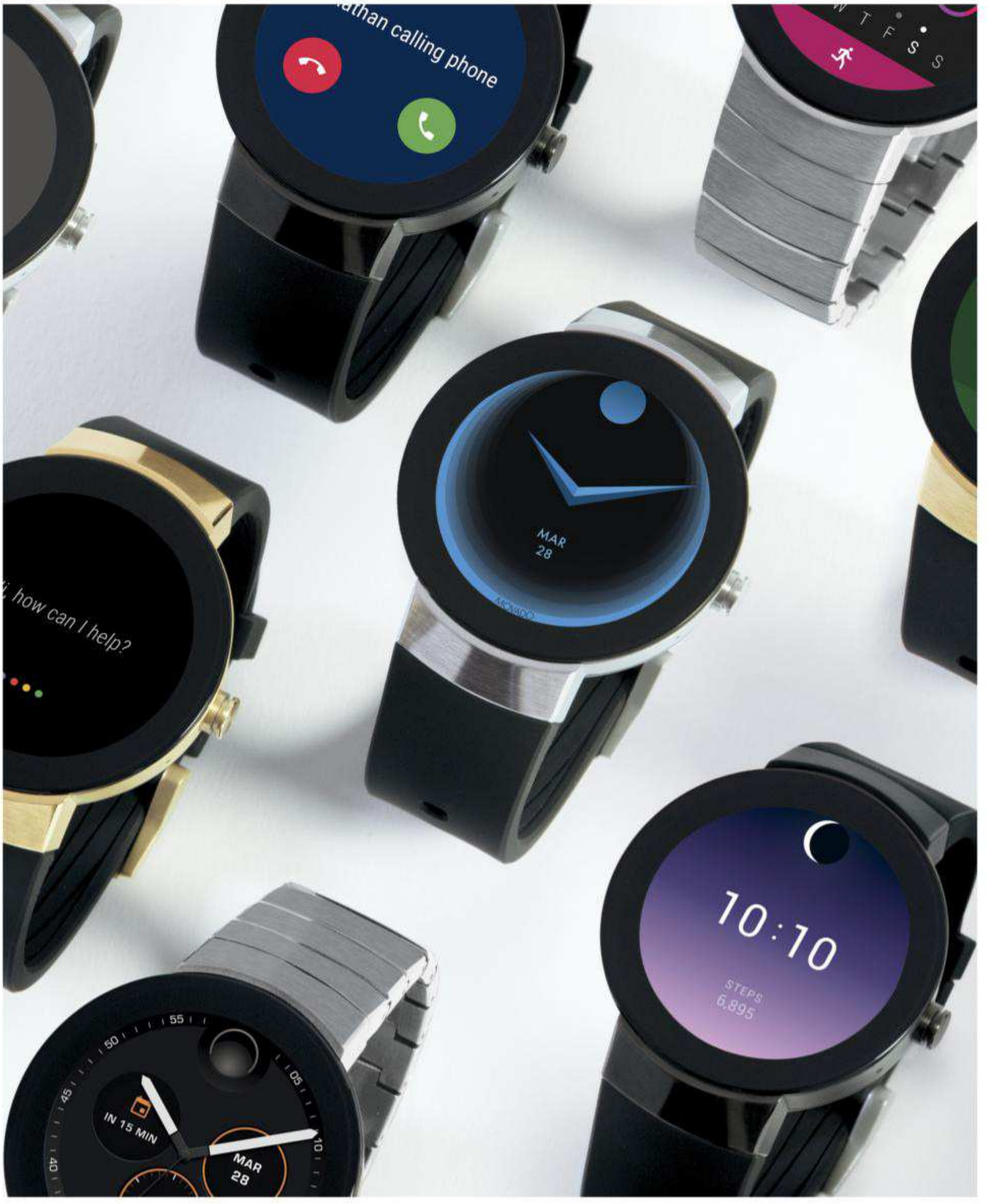

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SEP 2018 | CTRL+ALT+DEL

THE CODE THAT CRASHED THE WORLD

THE UNTOLD STORY OF THE MOST DEVASTATING CYBERATTACK IN HISTORY

P. 52

BY ANDY GREENBERG

HOW DOES GOOGLE CLOUD KEEP ITSELF SAFE FROM HACKERS?

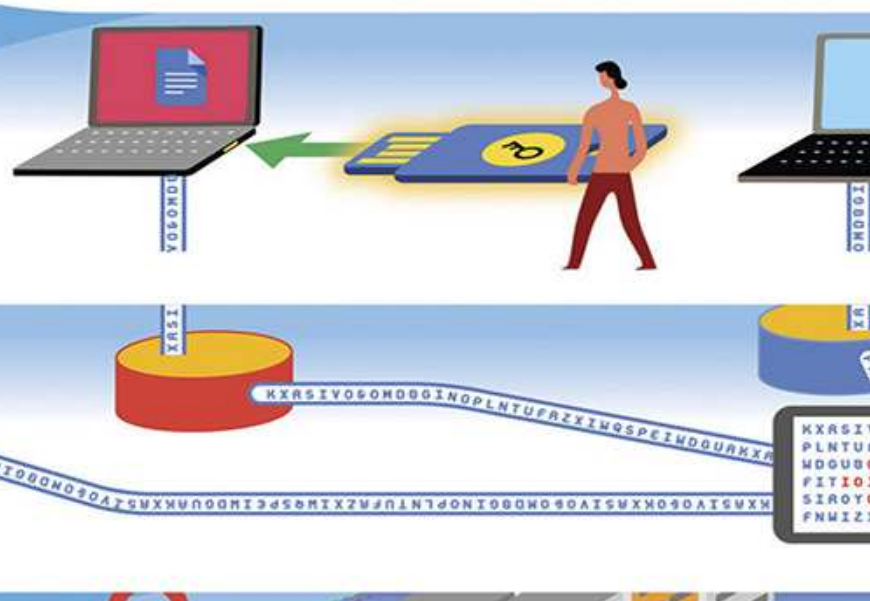
INSIDE GOOGLE CL

1. OPERATIONS

A global team of over 900 security experts monitors the system 24 hours a day, 7 days a week, 365 days a year — detecting and responding to attacks or issues.

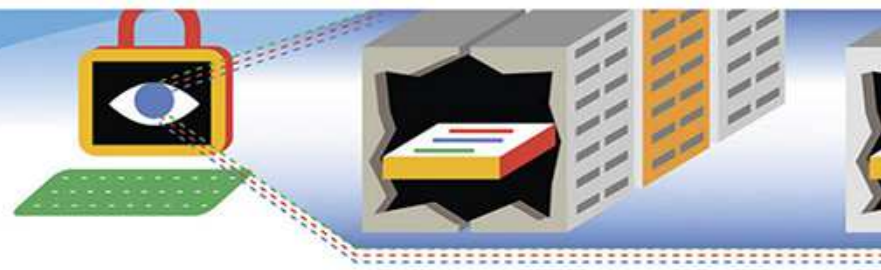
3. IDENTITY

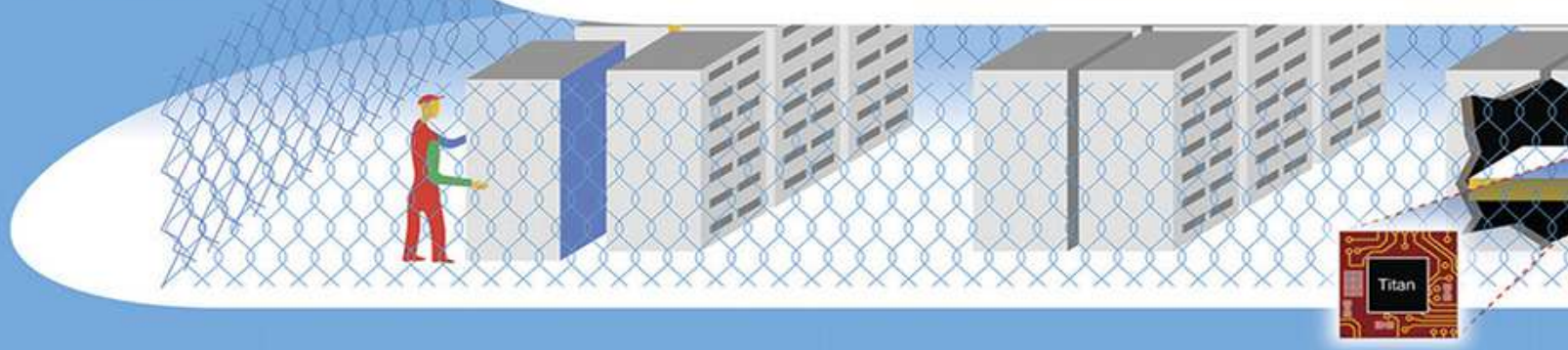
Users and machines must strongly authenticate for any access to data or services.

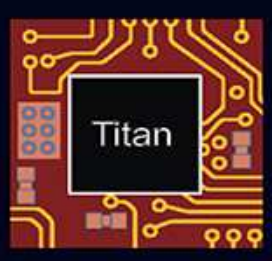


5. SOFTWARE

The integrity of firmware, operating systems and the rest of the software stack is verified, ensuring that unauthorized code is not allowed to run.







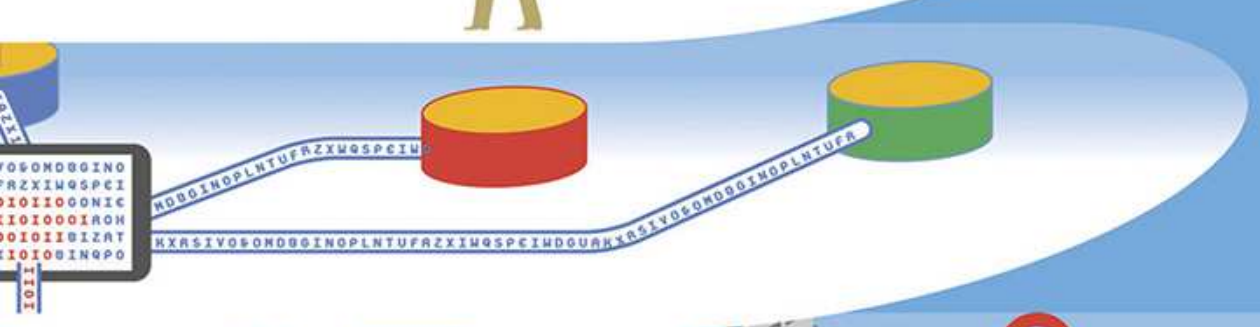
To help ensure a secure foundation, Google Cloud servers and peripherals contain an embedded Titan Chip — a mechanism purpose built by Google in order to verify the baseline security of the entire system. Before a server can even boot up, the Titan Chip must first confirm the integrity of its firmware and other low-level software — vetting the infrastructure before it even goes online.

OUD

GOOGLE CLOUD IS DESIGNED AS A MULTI-LAYERED SECURITY SYSTEM, A COMPREHENSIVE APPROACH FROM THE GROUND UP THAT OFFERS SAFETY AND PEACE OF MIND FOR BUSINESSES.

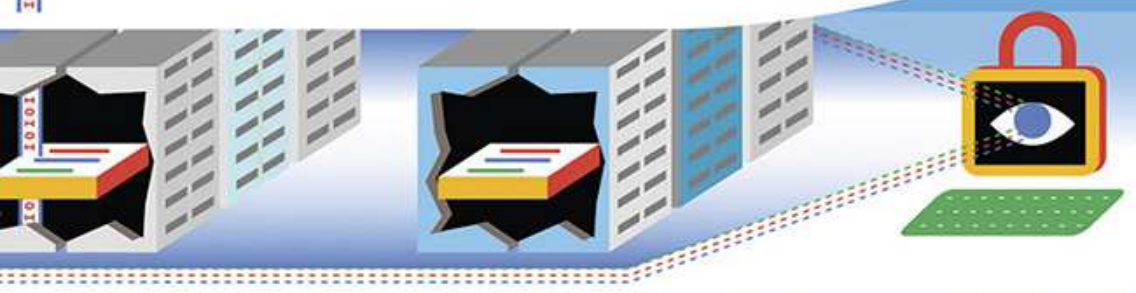
2. NETWORK

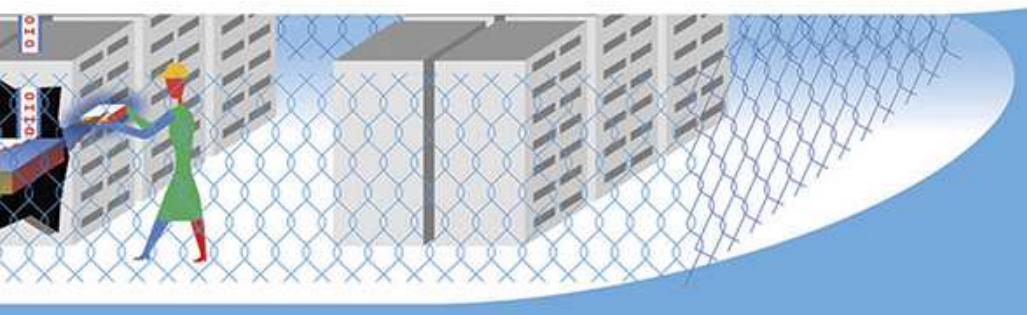
Connections to Google Cloud services are encrypted and multiple layers of defense are in place to help protect customers against network attacks like Denial of Service.



4. STORAGE

Data at rest is encrypted by default and then distributed for performance, reliability and to help guard against unauthorized access.



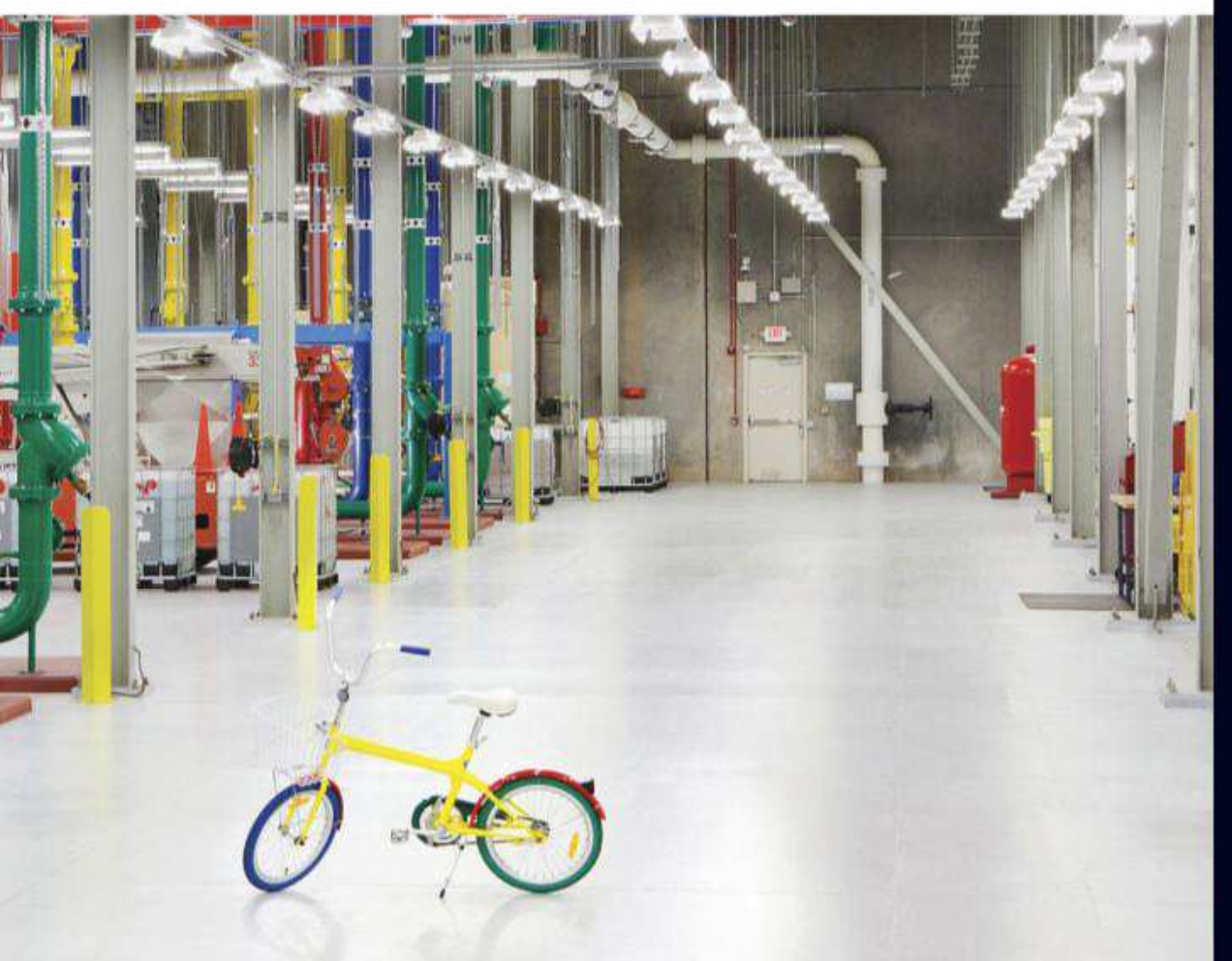


6. HARDWARE

Located around the globe, Google's data centers are high-security compounds housing the servers and other hardware that run Google Cloud.

To ensure that users are who they say they are, users across the globe must provide usernames, passwords and then tap a physical Security Key that is inserted into their computer or connected via NFC or Bluetooth before they access sensitive applications. Once tapped, the device sends cryptographic proof to Google Cloud that an actual person — and not a remote hacker — is present and providing their credentials. Since implementing Security Keys internally for its employees in 2011, Google has had no reported or confirmed account hijackings — security it offers to industries across the world and Google Cloud customers.

BY CREATING A REVOLUTIONARY CLOUD INFRASTRUCTURE FROM THE GROUND UP — AND THEN OFFERING IT TO THE WORLD



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PAGE 84


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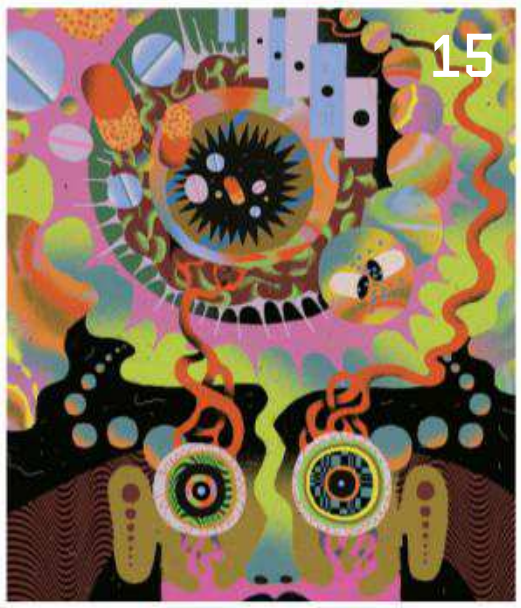

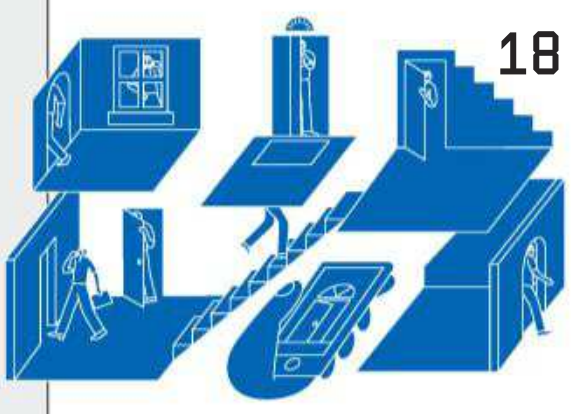

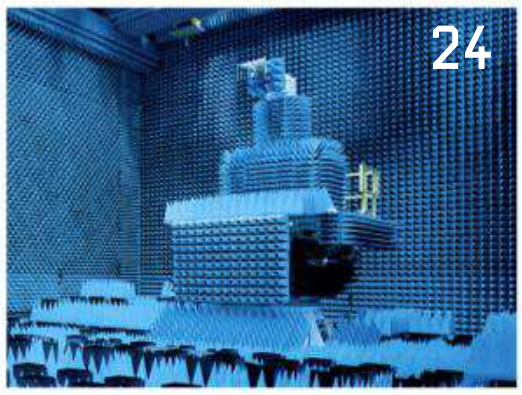

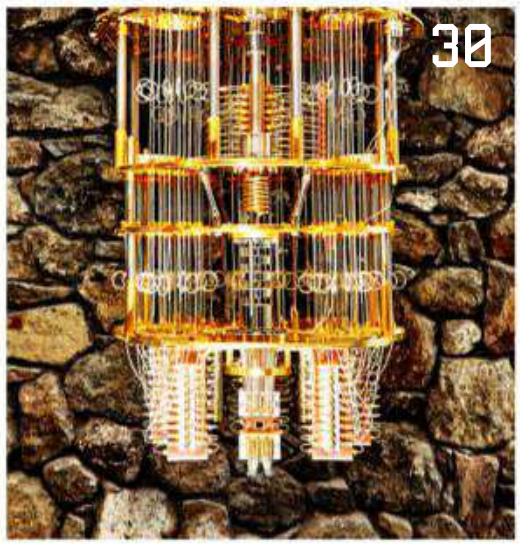

GADGET LAB

SIX BY SIX

ON THE COVER
Illustration for WIRED by Mike McQuade.

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THE BEST RUN
SAP

Daniel Alarcón in San Francisco in 2013.

POWER BROKER

When **Daniel Alarcón**, a New York–based writer and the executive producer of NPR's *Radio Ambulante* podcast, began reporting on Hurricane Maria's aftermath in Puerto Rico (page 84), one name kept surfacing: Jorge Bracero. The electrical utility worker had become a one-man news outlet, providing updates on the (painfully slow) progress in restoring power at a time when local distrust in government and media ran high. Alarcón even heard Bracero's name in a comedy show in San Juan and marveled at the audience's knowing reaction. "He was this cultural touchstone for people," he says. "After that I was like, I've got to talk to this guy."

When **Adrienne So** joined WIRED as an editorial fellow more than a decade ago, part of her job was to fact-check stories about gadgets and gear. "I ended up spending a lot of time hanging out in the Gadget Lab," So says. "I could not believe this was an actual job that people got to have." Now she has that actual job, as a senior writer of gear reviews. In this issue, So, who lives in Portland, Oregon, with her spouse and young children, gives readers the lowdown on kid-friendly electric cargo bikes and the latest generation of breast pumps.

In **Andy Greenberg**'s July 2017 feature on Russia's cyberwar against Ukraine, he warned that the Kremlin's attacks on its neighbor's infrastructure would soon play out in the rest of the world. Just one week later, Russia's hackers unleashed the NotPetya malware, a worm that spread globally from Ukraine to become the most costly cyberattack in history. "That prediction came true much, much faster than I expected," Greenberg says. In this issue (page 52), he describes the pandemic from the perspective of one victim: the world's largest shipping company, Maersk.

Rena Effendi, a photographer based in Istanbul, gravitates toward projects related to human rights. For this issue, she photographed a team developing a sensor network that predicts when and where air strikes in Syria will hit, giving innocent civilians a chance to survive their country's civil war ("Every Second Counts," page 73). I wanted to learn more about how new technology and innovation can actually be used to save lives in a conflict," she says. Effendi's work has appeared in *National Geographic* and *The New Yorker*; she's currently working on a project on the Spirit Lake Tribe reservation in North Dakota.

HEIDI SCHUMANN/THE NEW YORK TIMES/REDUX (ALARCÓN); AMY STEWART (SO); MARIA IONOVA-GRIBINA (EFFENDI); JOE PUGLIESE (GREENBERG)

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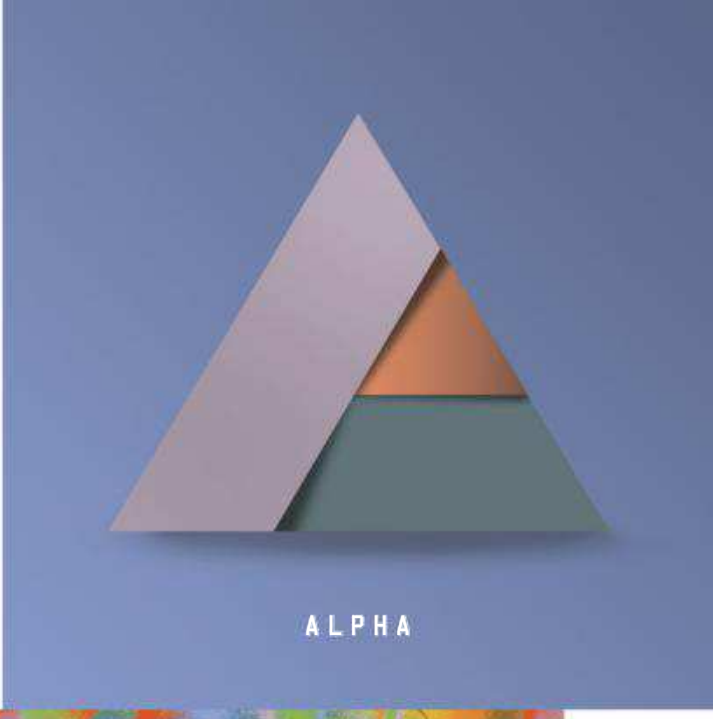
UPPER LIMITS
THE LAST THING WE NEED IS SPEED

BY VIRGINIA HEFFERNAN



SPEED HAS TRIPPED the light fantastic in America for more than 85 years. From Ritalin and Adderall to the twice-methylated *Breaking Bad* stuff, speed seduces both overbright founders and scurvy garage-dwellers. But it's not the drug for right now. Speed is not only deadly; it's defeatist.

It's been two sobering years. We'd do well to take stock of what we were blind to in the raciest days of Silicon Valley and the government-as-usual Obama years. When the writer Casey Schwartz gave up Adderall after having it define her youth, she identified deep regrets: "I had spent years of my life in a state of false intensity, always wondering if I should be somewhere else, working

SEPTEMBER ALPHA THEME:
SPEED

Time-traveling geologists, Fitbit's step children, quantum computing, podfasters, the joy of slow software, and more.

harder, achieving more." America is plenty intense—and it requires more freethinking from its citizens now than ever. It's time for a reckoning with reality, reflection and reform, principled action. It's also a time for civil disobedience. As grandiose as Adderall makes some people feel, the history of amphetamine as a drug of subjugation—used to compel obedience in soldiers, dieters, and unruly kids—haunts it.

In 1933, 46 years after Lazăr Edeleanu, a Romanian chemist, fatefully synthesized amphetamine—a mix of mirror-image molecules, levoamphetamine and dextroamphetamine—Smith, Kline & French picked it up and sold it as Benzedrine. Wouldn't you know, enterprising hacker-tweakers soon prised open the inhalers, liberated the speed-soaked cotton strips, and swallowed them.

Benzedrine as an "alertness aid" then shipped out to war. Months after the attack on Pearl Harbor, the drug was, quite literally, weaponized. Military commanders, writes Nicolas Rasmussen in *On Speed: From Benzedrine to Adderall,* greatly feared another humiliating epidemic of "shell shock" like the one that had crippled the Allied armies of World War I. To keep soldiers looking on the bright side of war, armies began provisioning the men with amphetamines. Psychiatrists on the battlefield rechristened shell shock "operational fatigue," and soldiers were relieved to hear they had a manly sounding physical ailment, eminently treatable with more Benzedrine. *Get back out there, Private.*

Combat itself was changed by speed. Speedfreak servicemen of the 1940s made for gung-ho, wild-eyed fighters as the drug supplied them with fool's courage. They hurled themselves into battle where they might otherwise have been held back by less thrilling but more adaptive human traits: anxiety, prudence, conscience. Commanders liked what they saw, and kept their men dosed.

When the soldiers came home, many were addicted, and their wives were the nation's next good soldiers. They reproduced the logic of the battlefields: They sucked down amphetamines to wage war on bodies—their own. The postwar obsession with thinness developed in tandem with the speed trade. By the end of the '60s, 9.7 million Americans used prescription amphetamines. Of those, hundreds of thousands were addicted. The everyday tweakers jittered along, subduing their fears and hungers with the pep pills that were now dyed and looked like candy.

In 1969, after speed killed a dieting woman, an investigative journalist for *Life* magazine, Susanna McBee, published a bombshell exposé about the overprescription of pills for weight loss. McBee made a tour of doctors' offices, and—after cursory interviews—was able to cop bags and bags of darling little tablets. Of course McBee had no weight to lose. But the drug trade now battened on the styling of female flesh as a disease.

YOU'D DO WELL TO LAY OFF THE STARCH AND READ SOME BETTY FRIEDAN ON THE SLAVERY OF SCUT WORK.

From soldiers to dieters to children. After McBee's article, and more deaths traced to diet pills, weight-loss speed became more tightly regulated. But speed changed shape. Just as "operational fatigue" and "flesh" had been styled as pathologies, distractibility got a pharma-world makeover—and became ADHD. Ritalin prescriptions for kids took off in the 1990s. By 2011, 3.5 million children in the US were on stimulants. A recent formulation, Adzenys, is aimed at first graders and up: It's orange-flavored and melts in your mouth.

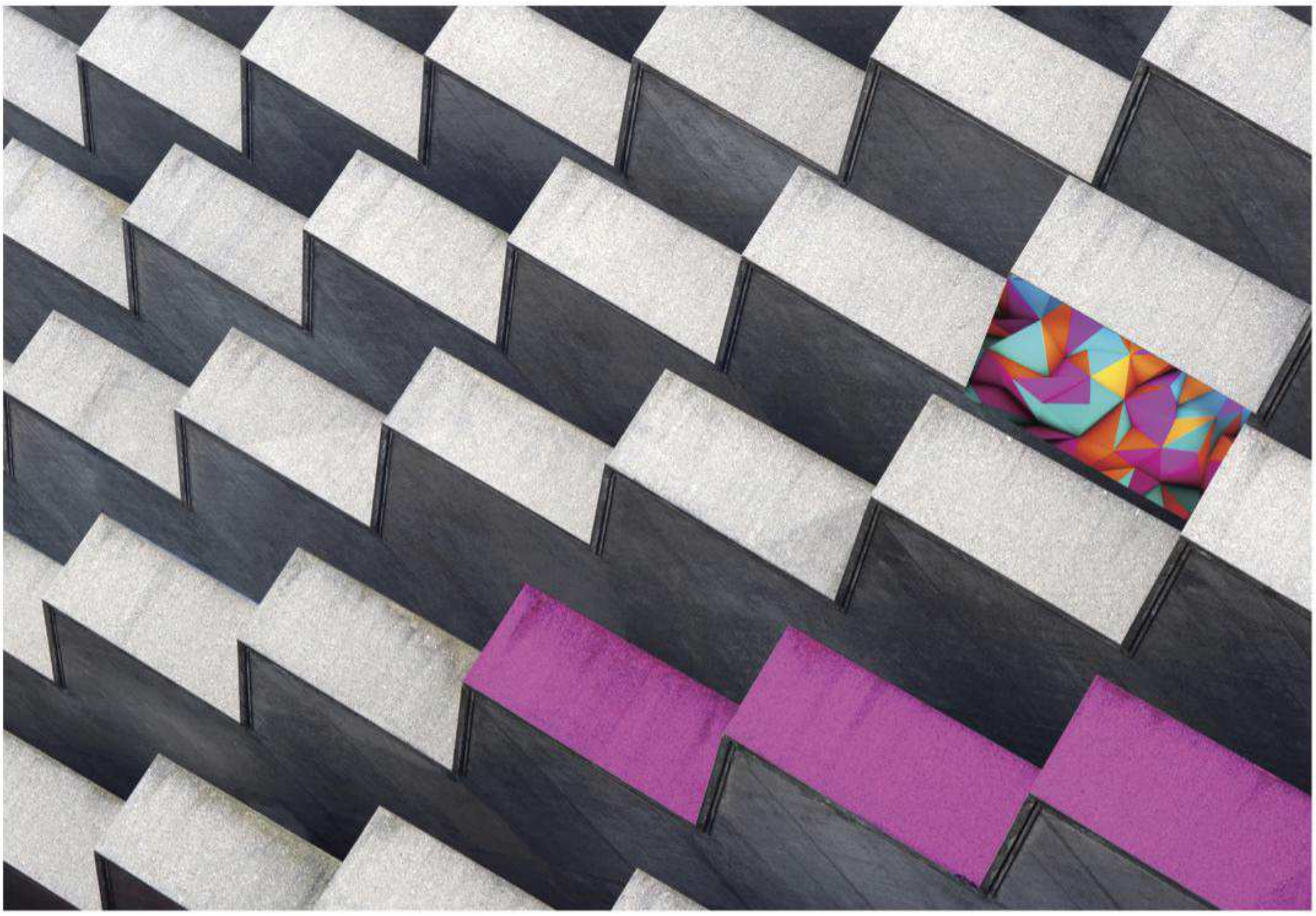
Speed can give kids a wonderful A-student experience. Of course parents want their kids to have that. To know the pleasures of conformity is a kind of bliss; those who pretend otherwise must never have feared that their eccentricities would disqualify them from life. But eventually the wandering mind, the hunger, and the anxiety return.

Speed gooses certain receptors to fake a body out, making it feel tight, urgent, self-important. On speed, you tend to embrace monotonous chores, especially asocial or servile ones, like arid sessions of dusting or coding, as the tiny muscles that line the walls of blood vessels contract. Speed also curbs mucus, while relaxing the lungs. So while users have symptoms of fear that may read as excitement, they also breathe easier.

Eventually, though, congestion returns. The mortal coil tightens. When it does, you may wonder: Why am I taking apart iPads and starching sheets? Good question, and you'd do well to lay off the starch and read some Betty Friedan on the slavery of scut work. Also, sleep. But if speed calls you back, it's because the

Virginia Heffernan *(@page88) is a regular contributor to* WIRED. *She wrote about annoyance in issue 26.08.*

THE ART OF ESSENCE



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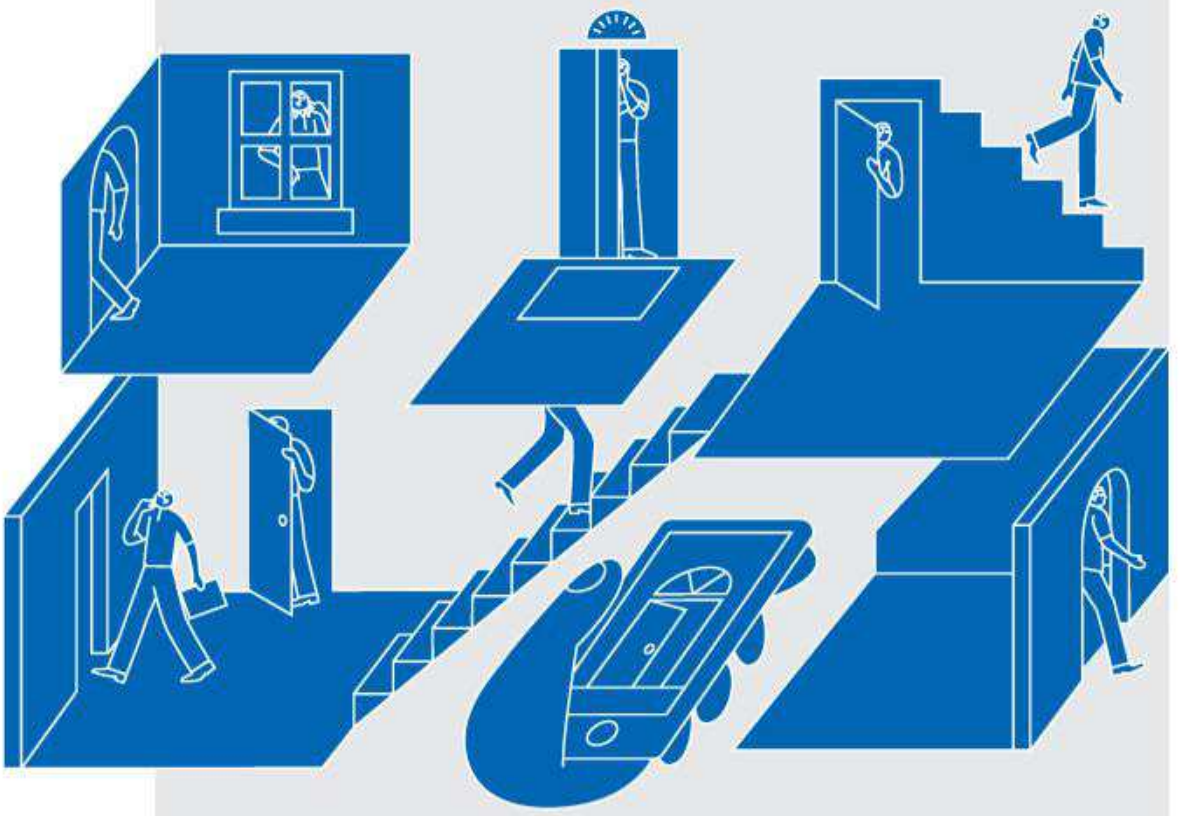
power to rise to social demands that elude undrugged brains—that just feels too good.

It's not immoral to want relief from being too slow, scared, and fat—too disappointing to your commanders. But chasing relief with speed could set you up for brain damage and psychosis. Worse, under the guise of fraud liberation, it locks you into life-draining repetition. You think you're being gloriously "productive"—even if what you're producing is expense reports and *Fortnite* kills—without noticing that you're missing the reasons for being: food, books, reflection, reform, engagement, adventure, rest, and meaningful work.

Why would anyone submit to this? Years ago, I stumbled upon an illustration of meth's effects in Donna Tartt's *The Little Friend*. Danny takes a hit and "Tears rose to his eyes. The icy, disinfectant taste at the back of his throat made him feel clean: everything surface again, everything sparkle on the glossy face of these waters which swept like thunder over a cesspool he was sick to death of: poverty, grease and rot."

I tried Ritalin in graduate school. I did manage term-paper all-nighters under its influence, and stopped eating; I had the sense that people like bosses were pleased with undernourished, industrious me, that I was doing well by them. But the tensing of blood-vessel muscles evidently reads to my body not as euphoria but as a kind of stifled misery, and sometimes I'd mistake my loss of appetite for grief. More precisely: High on speed, I felt as though someone I loved dearly had recently died. Worse still, I felt too important and prolific to mourn, or even care.



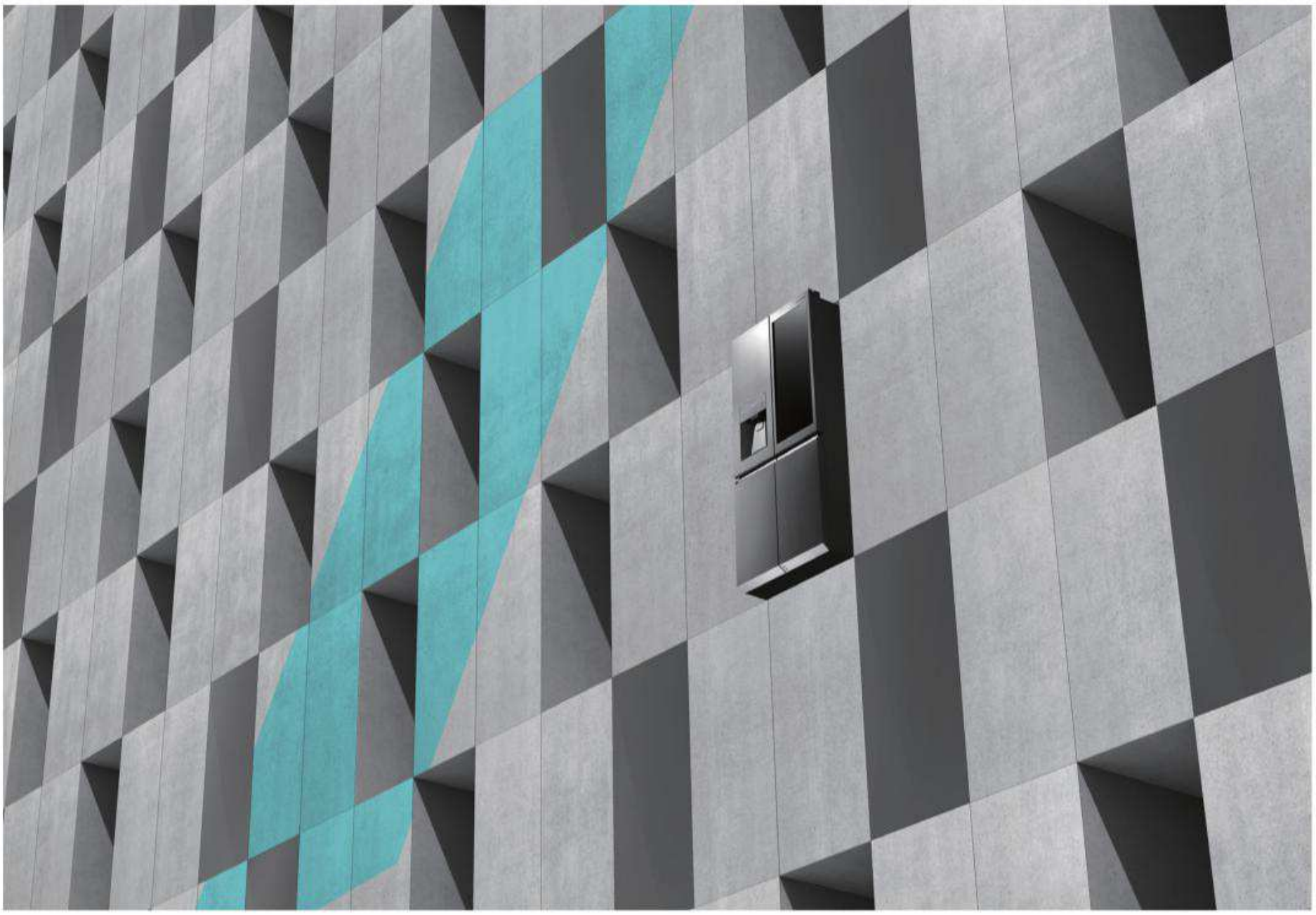
WHAT'S THE DEAL

HOME-SELLING APPS OFFER QUICK CASH

IF YOU PUT your house up for sale, know that it'll typically be on the market for about a month before you get an offer—an eternity when you're hosting revolving-door showings, paying two mortgages, or trying to move in a hurry. Now a new category of companies called iBuyers wants to slash that time span to three days or less. ¶ Think of them as house-flippers that work for you. Sellers fill out an online questionnaire, and an iBuyer uses proprietary modeling to assess the home's value. The company then makes an all-cash offer within 72 hours, sight unseen. (The iBuyer keeps a 6 to 10 percent commission off the price.) They make light renovations and relist the house at a markup. Home buyers can browse and make an offer via app. ¶ The field's forerunner is Opendoor, which is already in 12 markets and aims to expand to 20 by year's end. In June, the startup raised $325 million from investors like Lennar (the nation's largest homebuilder) and VC firm General Atlantic, bringing its value to $2 billion. Meanwhile, competitor Offerpad has raised a total of $410 million. Even traditional listings giants are copping the business model with programs like Redfin Now and Zillow's Instant Offers. ¶ While these startups' fees may skim thousands from a home seller's profit, for harried movers the prospect of a two-day turnaround—and cash in hand—may be worth it. Some iBuyers are even offering to hire your movers for you. Just open your wallet and get out of the way. —CAITLIN HARRINGTON

JAMES GRAHAM

THE ART OF ESSENCE



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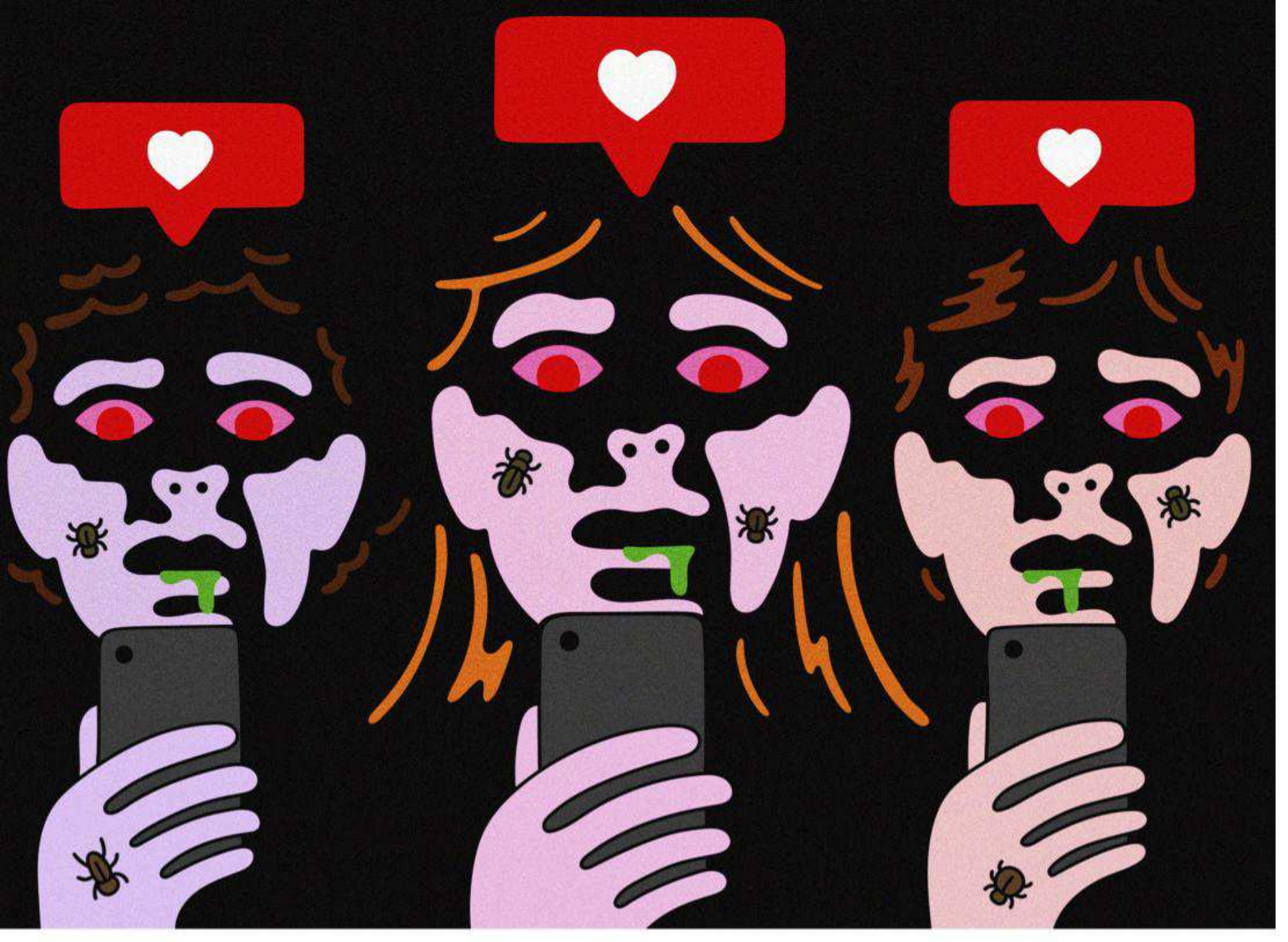


HUMAN PARASITES
HOW SOCIAL MEDIA ZOMBIFIES YOU

YOU'VE HEARD THAT social media is screwing with your brain. Maybe you even read about it on social media. (So meta; so messed up.) The neurochemical culprit, dopamine, spikes when you like and get liked, share and are shared. You've probably also heard scientists compare the affliction to drug or alcohol addiction. That's fair. The same part of the brain lights up.

Scroll, scroll, scroll. It's a phenomenon now so pervasive that it's got a name: zombie scrolling syndrome. (The security company McAfee coined the phrase in 2016.) We are the undead of lore, shambling through the world, moaning and groaning with half-closed eyes. I'd like to be able to tell you this is a fantastical bit of exaggeration, that we shouldn't be so hard on ourselves. I can do no such thing.

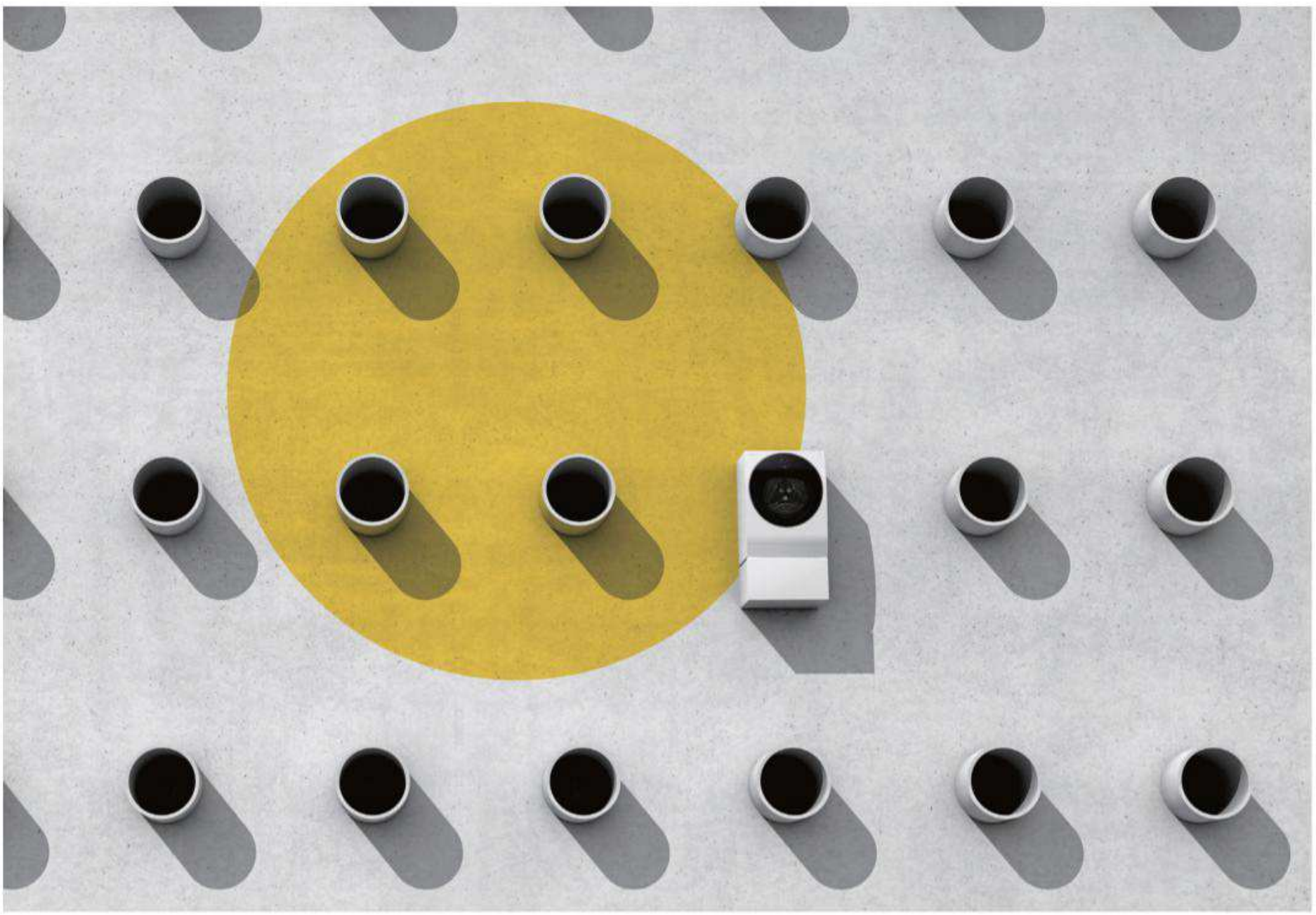
By staff writer **Matt Simon,** *whose new book,* Plight of the Living Dead, *comes out in October.*

The analogy, it turns out, has legs. Consider parasites. An astonishing number of them exist in nature, from worms to wasps, and some have the power of mind control. Or, said another way, zombification. And these fiends are doing it in—*gulp*—ways that bring to mind social media.

Take the jewel wasp. She grabs a cockroach twice her size and drives her stinger through the poor thing's neck and into its head, feeling around the brain before injecting nonlethal venom in two precise spots. (OK, not quite like Facebook, but stay with me.) Post-surgery, the cockroach just keeps grooming itself while the wasp drags it into a burrow by its antenna. The wasp then lays an egg on the cockroach's leg, seals the tomb, and goes about her life.

In a few days, the wasp egg hatches into a larva that latches onto the roach and drinks its bodily fluids. Again, the bug doesn't complain. It's not paralyzed; it's fully capable of breaking out of its prison. But the roach doesn't. As the fluids run dry, the larva burrows into the body to eat the organs one by one, hollowing out the

THE ART OF ESSENCE



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roach's abdomen while the thing is still alive (read: undead). Eventually it emerges as an adult wasp, finally killing its host.

According to researchers, the wasp's secret appears to be—wait for it—dopamine. The wasp loads up its venom with the neurotransmitter, and that cocktail alters the roach's behavior in ways scientists are only beginning to understand. Weirdly, in cockroaches and other creatures, dopamine regulates grooming, hence the insect's fanatical insistence on cleaning itself instead of running for its life. (Not like humans would ever primp for a *totally* natural and spontaneous selfie.)

The weapon of choice for other zombifiers is serotonin, another well-studied neurotransmitter. There's a tiny worm, for instance, that begins life in the stomach of crustaceans called amphipods. Then the worm finds itself with a problem. To live, it has to get into the stomach of a bird, which means it needs its host to get noticed. Complicating things, fish love to eat amphipods. That's bad for our protagonist: In a fish belly, the worm will dissolve.

So the worm mind-controls its crustacean to spend more time at the pond's surface, where it's likelier to draw the attention of birds. That little baby worm can even change its host's color to a more conspicuous hue. The worm itself isn't releasing serotonin; somehow it's short-circuiting the amphipod's nervous system to overproduce the chemical. Researchers think this may cause the victim to mistake light for darkness. Instead of diving into the safety of the murky depths, it ascends to the surface—and to death from above.

Whatever their strategy, zombifying parasites are hacking biology. And so, with their A/B-tested, keep-you-permascrolling tactics, are the titans of social media. Like any living creature, we are manipulable—our brains are chemical soups, programmed to need and be needed. Prehistorically, it's what helped us stick together to not get eaten. "It was clearly adaptive to be so sensitive to social stimuli," says UCLA psychologist Patricia Greenfield. "But evolution never expected that we would be getting social stimuli from people we don't even know." We're not only vulnerable, in other words. We also lack defenses.

There's a good reason that more than half the organisms on earth are parasites: If you live off the nutrients and energy of someone else, you don't have to run around and hunt for yourself. It's a hell of an effective strategy. And one thing is clear: You don't want to be the hunted.

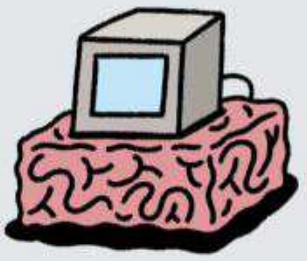
But there might be hope. Not every parasitic relationship ends in death. Take it from crickets.

All around the world, threadlike critters called horsehair worms grow in the bellies of crickets, feeding on their juices. Once the worms get big enough, they persuade their hosts to do the unthinkable: leap into a stream or pond and risk drowning (or death by fish). In the water the worm makes its move, drilling through the cricket's belly and swimming away to find fellow worms to mate with. Amazingly, the cricket can survive a parasite many times its length squirming out of its body, provided it swims to shore afterward.

IF YOU LIVE OFF THE ENERGY OF SOMEONE ELSE, YOU DON'T HAVE TO HUNT FOR YOURSELF.

Scientists know the horsehair worms are releasing a chemical concoction that instructs the crickets to go full kamikaze. But in this case, the cricket does well by putting its life in danger and jumping in the drink—if it can't get rid of the worm, the body snatcher will die in its belly and kill its host. Biologists call this, no joke, the mafia hypothesis: Give in to the bullying or die.

So we don't have to be the cockroach or the amphipod. We can be the cricket, with the power to purge our systems of zombifying parasites. When you uninstall Facebook on your phone or delete your Instagram account, you're taking a leap into that pond. You might belly flop, but it's unlikely you'll drown. And you won't get eaten by a fish. Probably.



JARGON WATCH

IPU

n. **Short for intelligence processing unit, a new kind of computer chip optimized for AI.**

Way back in the early 2000s, when the first Xbox came out, researchers discovered they could hack videogame consoles for scientific uses. It seems the devices' graphic processing units, or GPUs, designed to render flying gore and mayhem, also ran physics simulations faster than the CPUs in ordinary computers. ¶ Today, researchers still use GPU chips, not just for modeling but for artificial intelligence. Since each one contains lots of mini brains that crowdsource the work in parallel, they're good at big-data jobs like image recognition. Good, but not *awesome*. So companies are taking that idea and racing to create a new generation of chips just for AI. A startup called Graphcore (which just recently built a 2,000-teraflop AI supercomputer the size of a gaming PC) calls them IPUs. Get it? *I* for *intelligence*. ¶ As a name, *IPU,* unlike its bland _PU predecessors, seems minted for marketing. And for good reason. If Moore's law taps out soon, as many think it could, future gains in speed will come from specialization: niche chips designed for narrow uses. In a business ruled by lumbering giants, that's a bonanza for newbies, and the VC money is flying. ¶ Indeed, the semiconductor industry could soon resemble the cereal aisle of the supermarket. The explosion has already begun, with talk of DPUs (dataflow processing units), NPUs (neural processing units), EPUs (emotion processing units), and more. Computational muscle, fortified with the power of branding. —JONATHON KEATS

JARGON WATCH ILLUSTRATION BY LEON EDLER

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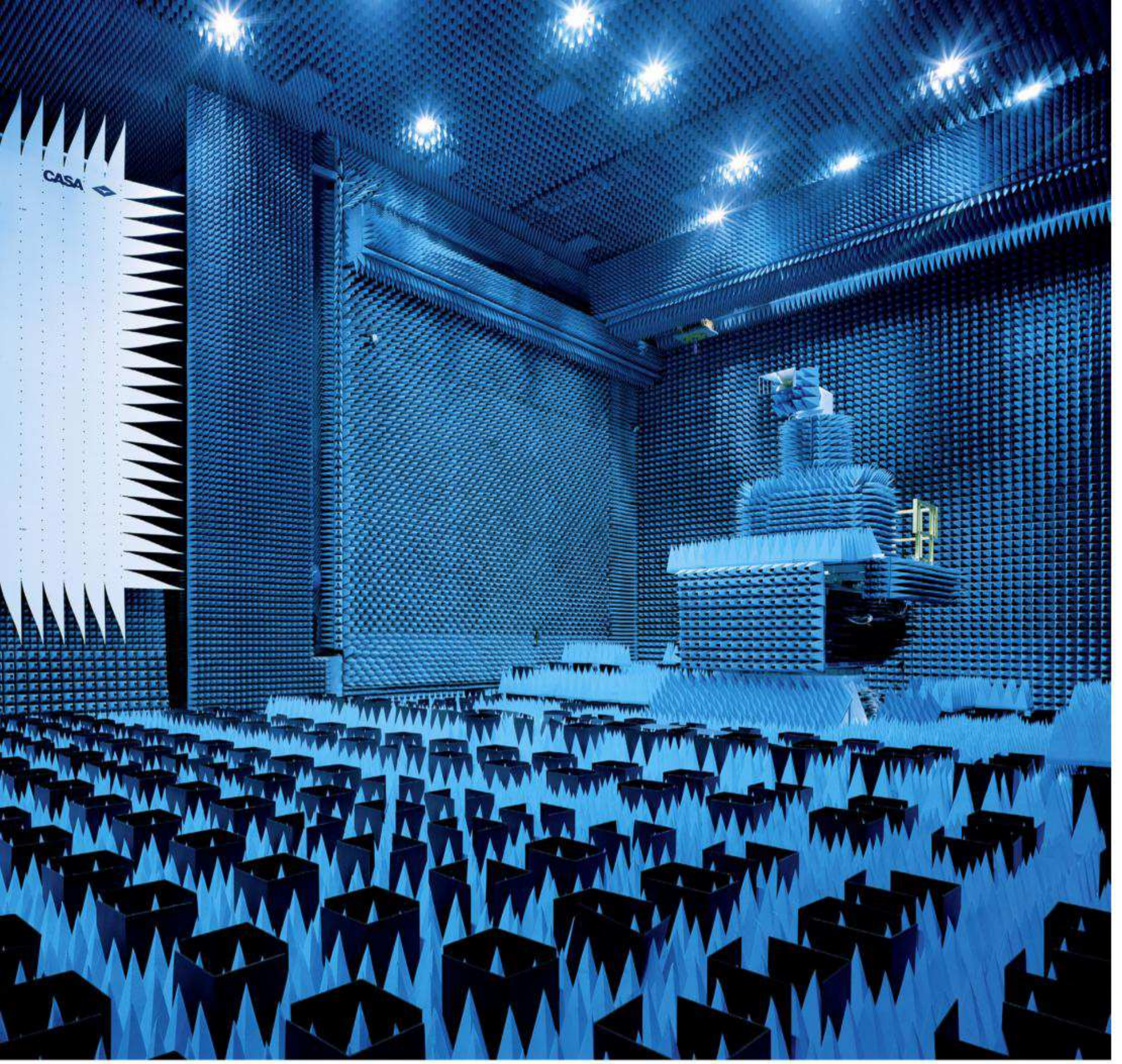

ALPHA

SPEED

WAVE POINTS
A SPIKY SPACE SIMULATOR

THE ELECTRIC-BLUE CHAMBER looks like a crowd of punk mohawks or the Night King's jagged skull. In fact, this 4,306-square-foot room is where antennas are torture-tested before being launched into space. ¶ Called the Hybrid European Radio Frequency and Antenna Test Zone, or HERTZ, it's located in Noordwijk, Netherlands. The 33-foot-high steel walls are studded with 18-inch foam pyramids that block external electromagnetic interference. Two tests are performed here: One measures radio waves from omnidirectional antennas, like the type rovers use to communicate with orbiters; another calibrates highly directional antennas, which spacecraft use to send data to Earth. Engineers bounce radio waves between an antenna and giant carbon reflectors to simulate signals hurtling at light speed through 500 million miles of space. ¶ Next up, HERTZ will test a radar antenna that'll search for liquid oceans during the 2022 Jupiter Icy Moons Explorer mission. If everything checks out, the system will leave this bristly cocoon for the vast wilderness of deep space. —LAURA MALLONEE

THE MARS SERIES. ANTENNA TEST ZONE, ESA, NOORDWIJK, THE NETHERLANDS, 2016

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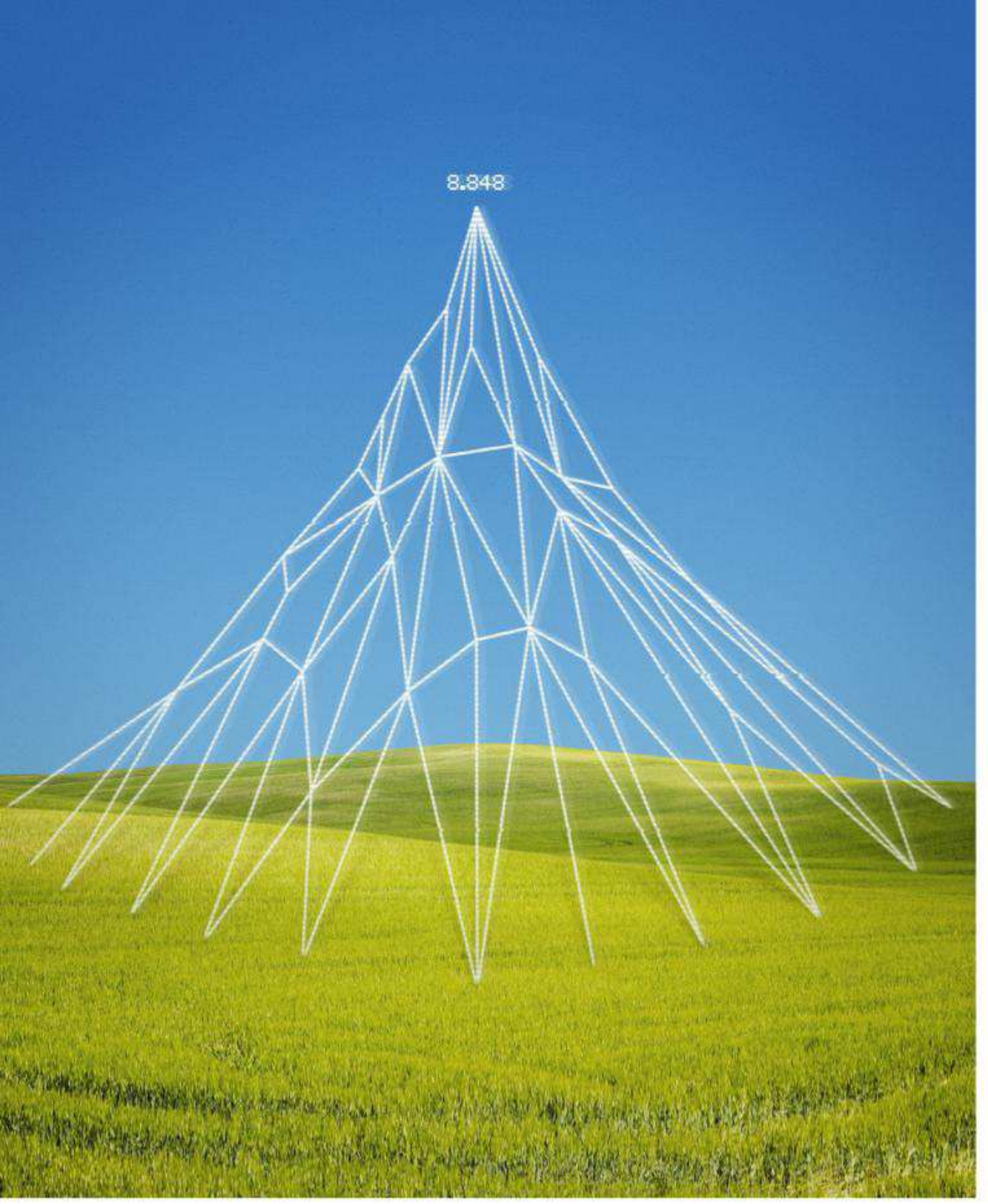

ALPHA

SPEED

PALEOVISION
HOW GEOLOGISTS SEE

IT'S AN ABNORMALLY hot day in September and I'm standing in a cattail marsh in eastern Wisconsin, trying to change the way my students view the world. They're all distracted—by the heat, homesickness, or the fact that they've lost a phone signal. The guys on the university hockey team are snickering about something. I've brought them here, in the first week of our introductory geology course, to investigate a mystery: Just in front of us, rising improbably from the flat expanse of the marsh, is a hill. About 50 feet high and twice as wide, it is made up of layers of loose sand and stones of many types. As we climb to the top, we can see that the hill snakes across the landscape like an upside-down river valley. My question for the students is: How did it form?

Geology has a PR problem; people associate it with musty museum collections and avaricious mining companies. As I hope my students will learn, though, looking at the planet through a geologic lens is something like strapping on an augmented-reality headset. It invites you, from your vantage point in the present, to summon up Earth's deep past and far future—to see these parallel worlds with your own eyes, like digital overlays. Not far from the marsh, for instance, is a limestone quarry. The slabs of gray rock seem unchanging now, but your headset reveals that they were once a coral reef in an inland sea. Below the former reef is a layer of golden sandstone, whose perfectly round quartz grains, pounded smooth by the ancient surf, speak of a beach that existed long before life came ashore. There are AR tools for mapping and modeling, but so far none is as immersive as geologic insight.

From the crest of the serpentine hill, I coax the students into posing hypotheses about its origin. They try various overlays. Was there a river here once? That would account for the sinuous form but doesn't explain why it's a ridge, not a valley. OK, how about a glacial deposit? That explains the variety of stones, but a bulldozing ice mass doesn't leave behind neat layers. The students are getting curious, drawn into the mystery, a little aggravated by it. Suddenly, someone has a crazy idea: Maybe this whole area used to be under ice, and maybe we're standing in the dried-up bed of a river that flowed in a tunnel under the ice. The headsets are working now: We're just 20 minutes from campus, but we're half a mile under a Pleistocene glacier. The mood on the bus back to campus is buoyant. We've connected with something old, wild, and real.

Most humans are chronophobes. We worry about where the time has gone, whether we're spending it wisely, how much of it we have left. Geology puts things in temporal perspective; it reminds us that, while the current version of the world is ephemeral, it's also intimately connected to countless others, long past and still to come. If I'm successful, my students will finish the class seeing backstories everywhere in nature, their sense of place and time on this old Earth irrevocably altered.

By **Marcia Bjornerud**, *a professor of geology at Lawrence University. Her book* Timefulness *comes out this month.*

ISTOCK

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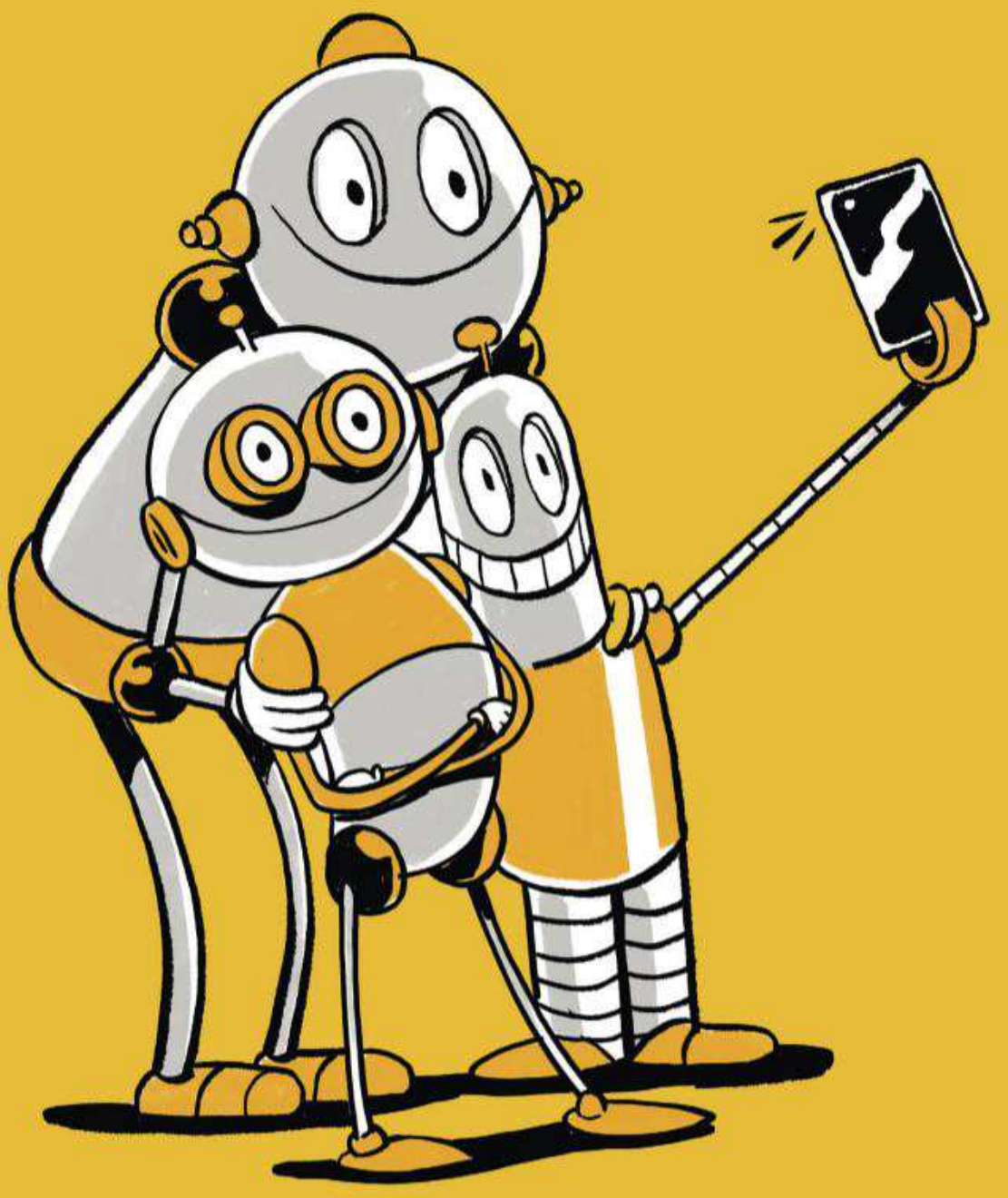

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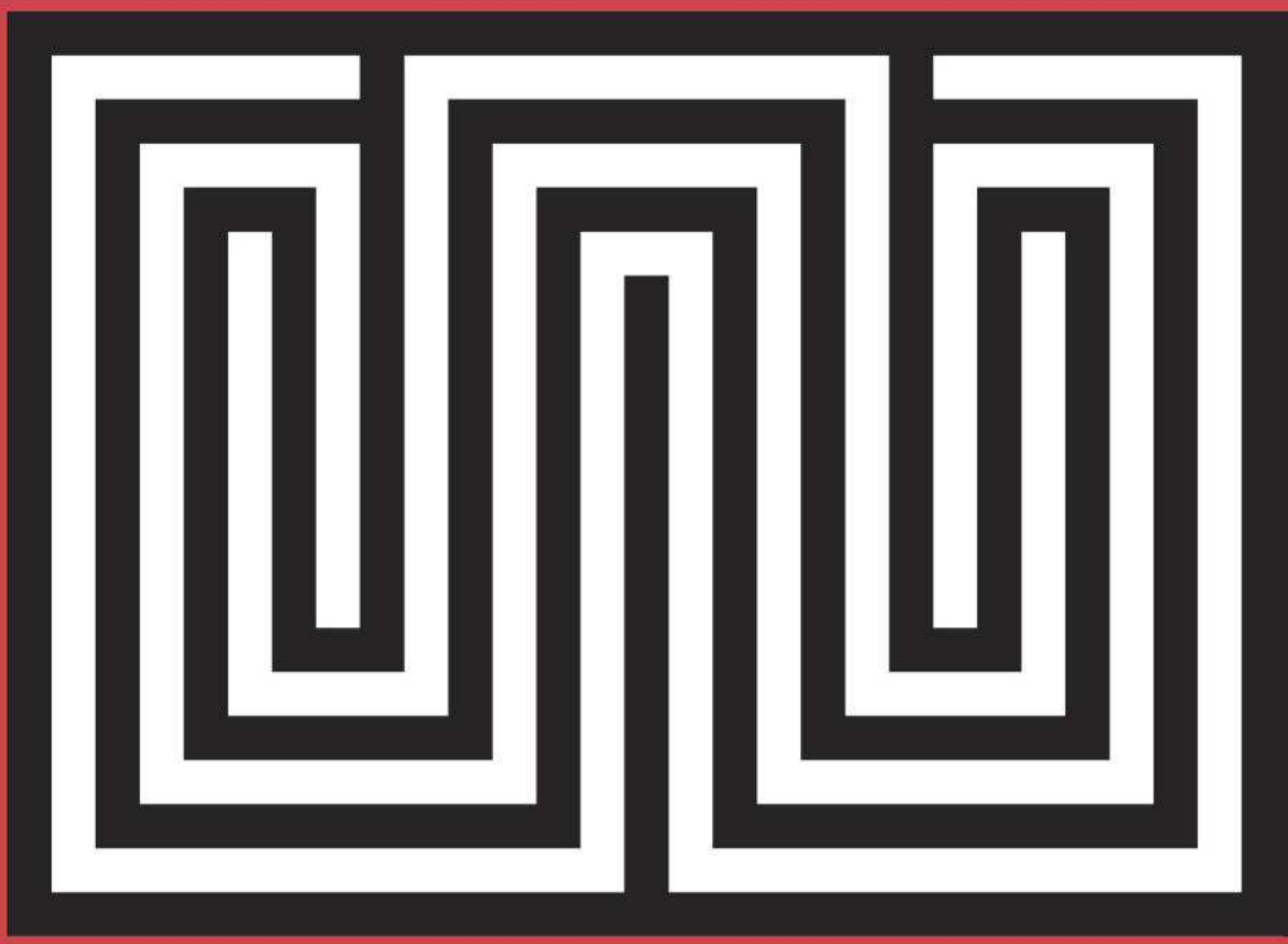

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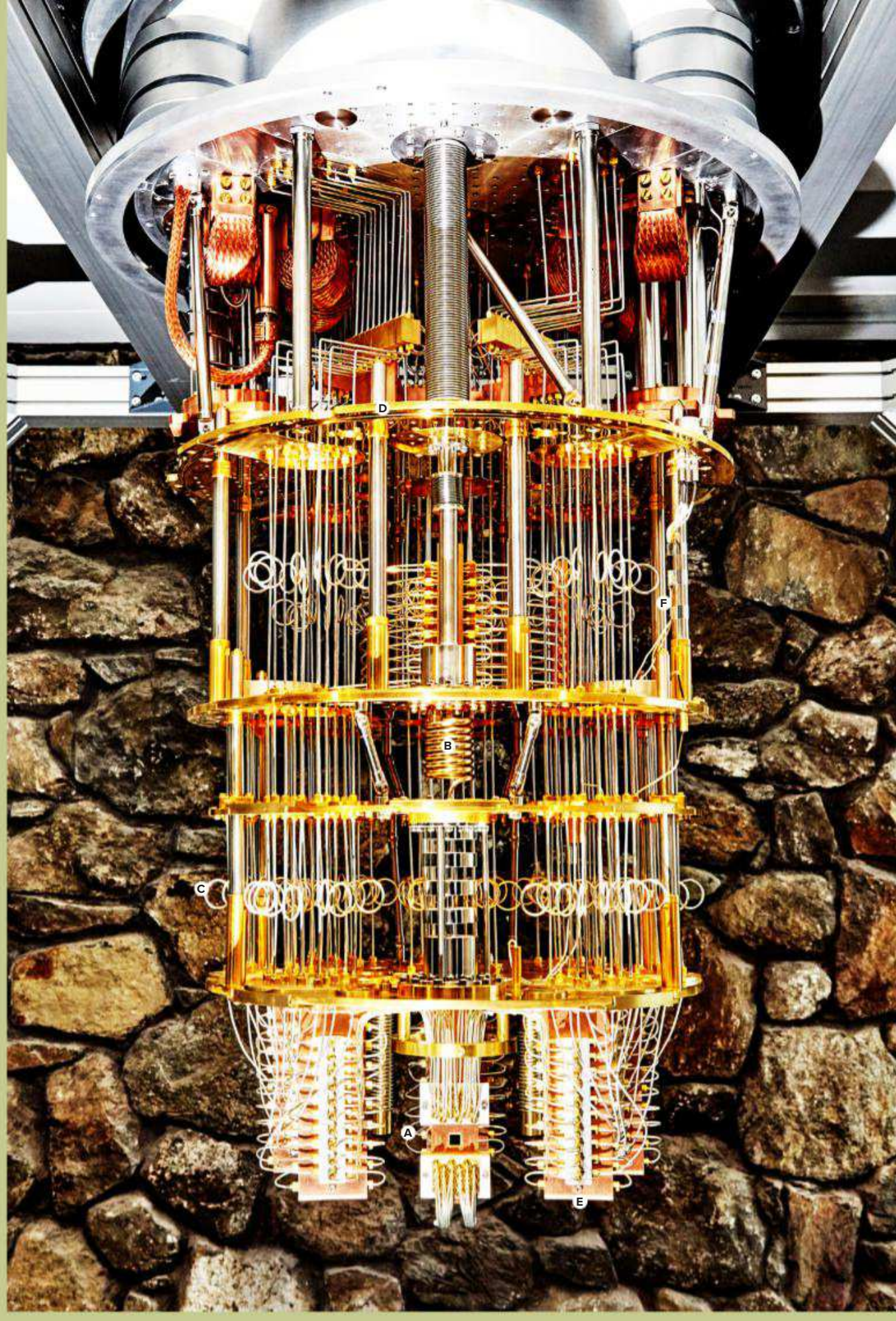
WIRED GUIDE

QUANTUM COMPUTING, EXPLAINED

IN THE BEGINNING, there were 1s or 0s. Now there are 1s *and* 0s, existing in both states at once (sort of). Superposition, it's called, and it's the physics underlying quantum computers. Say it with us: WTF. As a concept, quantum computing has been bewitching—and befuddling—researchers for nearly 40 years, promising exponentially more oomph than conventional machines. Finally, new hardware is making the possibility real. "This era feels like the late '50s as the first microprocessors were being developed," says Jerry Chow, who leads experimental quantum computing at IBM. His company and dozens of others love playing with these chandelier-shaped marvels (like IBM's machine pictured here), convinced they might help improve everything from car batteries to drug discovery. —TOM SIMONITE

Senior writer **Tom Simonite** *(@tsimonite) covers intelligent machines for* WIRED. *For an expanded version of this story, visit wired.com/tag/wired-guide.*



Hardware Breakdown

A. Processor
A tiny silicon chip—studded with qubits ("quantum" + "bits") made from aluminum circuits—operates at around 15 millikelvin, colder than interstellar space. (Qubits are delicate prima donnas—heat exhausts them.)

B. Heat Exchanger
The coil circulates helium (liquid or gas) to supercool the apparatus.

C. Conductive Loops
Stainless steel coax cables carry signals to and from the processor. Their curved shape prevents breakage as the machine chills.

D. Protective Coat
Exposed copper would tarnish and disrupt the cooling system, so vulnerable metal parts are plated with unreactive gold.

E. Isolators and Circulators
These components block noise and route signals.

F. Aluminum Tape
A low-tech fix corrals wires that link the control system to temperature sensors.

36

APPROXIMATE NUMBER OF HOURS IT TAKES TO CHILL THE COMPUTER FROM ROOM TEMPERATURE TO OPERATING TEMPERATURE

AMY LOMBARD

The Physics Behind Quantum Computing

1. Traditional computers break problems into bits—the 1s and 0s encoded on your hard drive. More bits means more processing power.

2. Quantum computers rely on qubits. At cold enough temperatures, they can take on a state called quantum superposition, something like being both 0 and 1 at the same time.

3. With bits, you can only work with the number you have. Qubits in superposition play with many more combinations of their 1s and 0s.

4. Algorithms exploit this state to eliminate incorrect pathways through certain problems. At the end of the calculation, the qubits collapse to normal 1s and 0s to reveal the answer.

2 Ways to Make a Qubit

Aluminum Circuit
Circulating an electrical current through superconducting metal on standard chips provides the quantum weirdness. Big tech companies like Google love this method.

Levitating Atoms
So-called ion traps use electromagnetic fields to isolate atoms (like strontium) whose quantum behaviors are controlled with lasers.

Ask a Quantum Code-Jammer

Theoretically, quantum systems capable of factoring huge strings of numbers could crack popular encryption protocols and expose your digital secrets. Dustin Moody, a mathematician at the National Institute of Standards and Technology in Maryland, is trying to prevent the datapocalypse. At the moment, he's optimistic.

What exactly is the danger?
Algorithms have been invented that could use quantum computing to completely break the encryption you depend on for things like online shopping or banking.

Yikes! How long have we got?
It's estimated that a powerful enough quantum computer could be built in 10 to 15 years.

So are we doomed?
We're running an international competition to create quantum-safe cryptosystems before large quantum computers are built. Average internet users won't notice—that's the goal anyway.

Phew.

Quantized Tomorrow

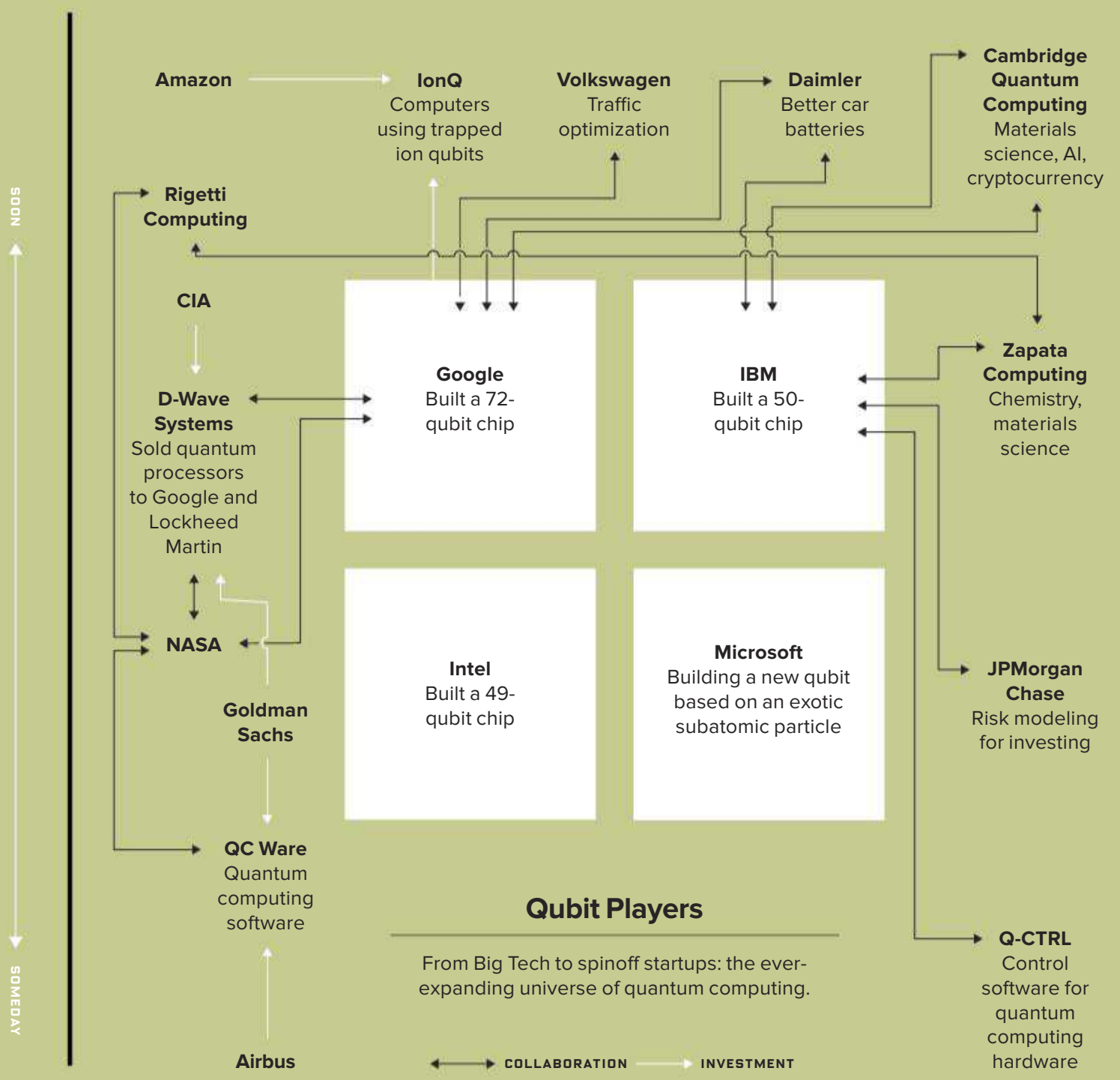
What a quantum leap in computing could do for us.

Global Cooling
Quantum computers can simulate complex molecular interactions, revealing how to make more efficient electric car batteries or mop up carbon emissions.

Miracle Cures
Better chemistry simulations will also speed up drug research by reducing lab grunt work.

Smarter Help
Quantum algorithms can do the math behind artificial neural networks faster than existing computers. Meet your robo-butler.

Faster Delivery
Everyday logistical puzzles, like plotting pizza delivery routes and coordinating factory workflows, can be parsed by quantum machines in no time.



A BITSY HISTORY: **1980** PHYSICIST PAUL BENIOFF SUGGESTS QUANTUM MECHANICS COULD BE USED FOR COMPUTATION. // **1981** RICHARD FEYNMAN COINS THE TERM *QUANTUM COMPUTER*. // **1994** A BELL LABS MATHEMATICIAN INVENTS A QUANTUM ALGORITHM THAT COULD BREAK WIDELY USED FORMS OF ENCRYPTION. // **2014** GOOGLE FORMS A LAB FOCUSED ON QUANTUM COMPUTING HARDWARE. // **2016** IBM PUTS A PROTOTYPE OF A 5-QUBIT QUANTUM COMPUTER IN THE CLOUD FOR ANYONE TO EXPERIMENT WITH.

STEP CHILDREN
THE LIFE OF FITBIT

AS JAPAN ENTERED the 1960s, everything seemed to be in motion. Construction swept through Tokyo as the city prepared to host its first Olympic Games. The Tōkaidō Shinkansen, the original bullet train, sped along the southern coast of Honshu. More cars filled the roads. The only thing *not* moving, it seemed, were people's legs.

Prosperity fostered convenience, which encouraged inactivity—or so a doctor reportedly told the founder of Yamasa Tokei Keiki. In response, the company released the world's first commercial pedometer, the *manpo-kei*. *Kei* means "meter," and *manpo*, "10,000 steps."

In East Asia, 10,000 had long been shorthand for plenty, or even infinite vastness, but affixed to a fitness gadget the number solidified. Once a medical researcher endorsed 10,000 steps as the threshold for being an "active" adult, manpo crossed from idiom to science and, in the process, became the best kind of goal: exact, plausible, and resettable. A wave of walking clubs overtook Japan.

Americans, wedded to their own conveniences, were slow to catch up. Sure, running took root as a pastime in the '70s, and an '80s fervor for "mall walking" led to hordes of retirees Rockporting their way through suburban gallerias. But quantified stepping didn't come to US shores until 2008, courtesy of entrepreneurs James Park and Eric Friedman. "I had been working like crazy at startups over the last three years and really let myself go in terms of fitness," Park said at the time.

Not long after, he and Friedman released the Fitbit Tracker. It looked like a clothespin had mated with a stapler: a tiny matte-black pincer with an even tinier lowercase *fitbit* printed in light gray, a handy reminder when you inevitably found it in the dryer. (Googling "fitbit laundry" pulls up nearly 15 million results.) A single button cycled through the display so you could see your march toward that magical 10,000, rendered as a blue flower. "Keep moving to keep the flower growing," read the user manual. A botanical Tamagotchi, feeding off your efforts.

There were numbers too—and oh, the numbers. They were our eyes turned inward, the power to see what our bodies had done and were doing. Metabolic rhythms, miraculous alchemies, made quantifiable for the first time outside our medical charts. We became mech pilots, armed with a brand-new instrument panel to steer our clumsy selves through the world. When you logged in to check your mech's maintenance records—*How many calories has it burned this week? How many times does it wake up on an average night?*—you saw those of your fellow pilots as well.

I remember the game. Not only did I have manpo to keep pace with, but mankind itself. The college buddy whose new role as father was snaring him 4,000 steps before the workday started. The colleague who walked to work while I took the bus like a sucker. Hell, I once strapped my tracker around my ankle for a four-hour bike ride, spinning up a European vacation's worth of footfalls. The prize was an anguished email from a rival wondering how I'd juiced my total.

As Fitbit introduced new products, the deceptions diversified. One step-fluffer taped his tracker to an electric saw blade and left it on overnight. Others gave their Fitbits to their dogs. Compared to them, my favorite hack—brushing my teeth like a coke-addled drum major—seemed downright Calvinist.

By 2014, Fitbit had a 67 percent share of the activity-tracking marketplace. It sold 21.4 million devices in 2015, the year it went public, and 22.3 million in 2016. Then smartwatches happened. If you were a serious athlete, you upgraded to a serious device. If you weren't, something like an Apple Watch just looked a lot cooler and worked with the rest of your app-driven life. By 2017, Fitbit's stock price had tumbled by more than half.

It made sense. At first, being a mech was fun—the numbers, the feedback, the idea that you could use it all to make yourself healthier, *better*. But in the decade since the Fitbit was born, another feedback device emerged and demanded even more attention. It, too, showed you glimpses of other people's lives, or at least the lives they wanted you to think they led. But your smartphone didn't bother with flower power. It asked not for your effort but for your *time*, and there was little reward.

Spurred by sales of its own watch, Fitbit's stock has recently twitched back to life. Meanwhile, more and more people are taking steps to distance themselves from their technological dependencies. These aren't literal steps. But they might be the healthiest steps of all. W

By **Peter Rubin** *(@provenself),* WIRED *senior editor and self-tracking runner.*

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MISSION CONTROLLER

DISABLED GAMERS GET A POWER-UP

By **Laura Parker**, *author of* Power Play: How Video Games Can Save the World.

THE FEDEX PACKAGE arrived at Mark Barlet's home in Harpers Ferry, West Virginia, on Christmas Eve 2016. He opened the box and gingerly pulled out a sleek black-and-white device with two large buttons: a prototype for the new Xbox Adaptive Controller. He touched the logo and tears came to his eyes. "I couldn't believe it," Barlet tells me. "I said to myself, 'We fucking did it.' "

Barlet, 44, is a disabled Air Force veteran. He injured his spinal cord in 1996 at Andrews Air Base in Maryland. He can walk, but he suffers from chronic pain. One evening in 2004, he was at home playing the multiplayer game *EverQuest II* with a friend in Nevada who has MS. "Suddenly, her right hand just stopped working," Barlet recalls. She didn't regain mobility for months. Deeply affected by the experience, Barlet started emailing and calling game companies to ask about modified controllers and other assistive tech. What he learned was discouraging. Few major gaming companies had even considered developing consoles for players with restricted movement. Later that year, Barlet founded AbleGamers, an organization that advocates for accessible gaming options.

Disabled gamers are a very real, very vocal demographic: AbleGamers estimates that there are more than 30 million of them in the US. But across all systems, videogame controllers are configured more or less the same: two thumbsticks, a D-pad, and a slew of buttons. Increasingly complex gameplay—think popular shooters like *Call of Duty* or fast-paced action games like *Assassin's Creed*—often necessitates rapid-fire button combinations, like tapping one repeatedly while pressing another, or moving both thumbsticks simultaneously. Motion controls, like those required for Nintendo's

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upcoming *Pokémon: Let's Go* games, are another challenge altogether.

For years, the disabled gamer community has compensated with switches: devices that allow people with limited mobility to control a game using different parts of their body, like their head, foot, or mouth. But switches, typically made by medical supply companies, can be expensive—up to $200 apiece—and clunky. "A lot of them are comically large or look like a medical device," says Erin Muston-Firsch, an occupational therapist who helps patients with spinal cord and brain injuries at Craig Hospital's Tech Lab in Colorado.

Other times, players make do however they can. Michael Phillip Begum is a 30-year-old gamer in Brownsville, Texas. He has a condition that prevents his muscles from growing, hindering physical activity. But for seven years he's been playing *Street Fighter* competitively under the name Brolylegs, moving a standard controller using his cheeks and tongue. Until the rise of social media, developers were clueless about how gamers with disabilities struggled, he says. "It was simply a choice we had to make. Can we play it? If we couldn't, we tried another game."

In 2010, Congress passed the 21st Century Communications and Video Accessibility Act, which requires companies to make laptops, tablets, smartphones, gaming consoles, and other tech that can be used by people with disabilities. "Though the act has a very narrow focus, I think that it was a catalyst in prompting gamemakers to rethink their existing franchises," Barlet says. The industry successfully lobbied the FCC for an extension; the new deadline is the end of this year.

In 2015, Sony added new accessibility settings to its PlayStation 4, including text-to-speech, closed captions, zoom, enlarged or bold text, and inverted colors. In August 2016, EA released one of its biggest sports titles, *Madden 17*, with expanded accessibility features such as color-blind support and brightness and contrast settings.

In July 2016, Xbox reached out to Barlet with an idea that had emerged from an internal hackathon: Microsoft wanted to create a videogame controller from scratch for people with limited mobility. Through AbleGamers, Microsoft staffers asked disabled players a barrage of questions about using controllers and switches. The gamers weighed in with critiques on early product sketches and tested out prototypes with their switches.

The Xbox Adaptive Controller, which will be released this month for $100, works with all titles on Xbox One and Windows 10 and can be customized for each game via app. Designed for gamers with restricted mobility, including those with cerebral palsy and spinal cord injuries, the device is compatible with most existing switches. Players can plug in foot pedals, for example, if they can't use their hands, or a QuadStick, which lets quadriplegic players sip or puff with their mouth to control movement onscreen. The controller also introduces Shift mode, which allows the player to change a button's function midgame. (So a button might control "jump" in one section and "shoot" in another.)

The Xbox controller represents a small victory for disabled gamers, but "it's not a Swiss army knife that will help everyone," Barlet says. Gamers with visual impairments, in particular, may be disappointed by the controller's lack of rumble packs, those vibrating devices that alert players when, say, they're near a clue. Barlet is also pushing for software improvements in games, adding features like rich soundscapes and resizable text.

In the meantime, the Adaptive Controller's upcoming release has other game companies scrambling to introduce their own accessible hardware. ("Nintendo is way behind," Barlet says.) Earlier this year, PlayStation senior producer Sam Thompson gave a two-hour presentation to some of Sony's game developers about UX design for disabled players—from sightless gameplay prototypes to nonverbal support. "This year we've been contacted by all the big studios," Barlet says. "The things they're asking go far beyond what the Accessibility Act requires. They're finally looking to make games not only compliant, but truly enjoyable by people with disabilities."

Still, despite the recent groundswell, Barlet harbors no illusions. "We know what companies want: business," he says. A new customer base of more than 30 million gamers may give game developers the push they need.

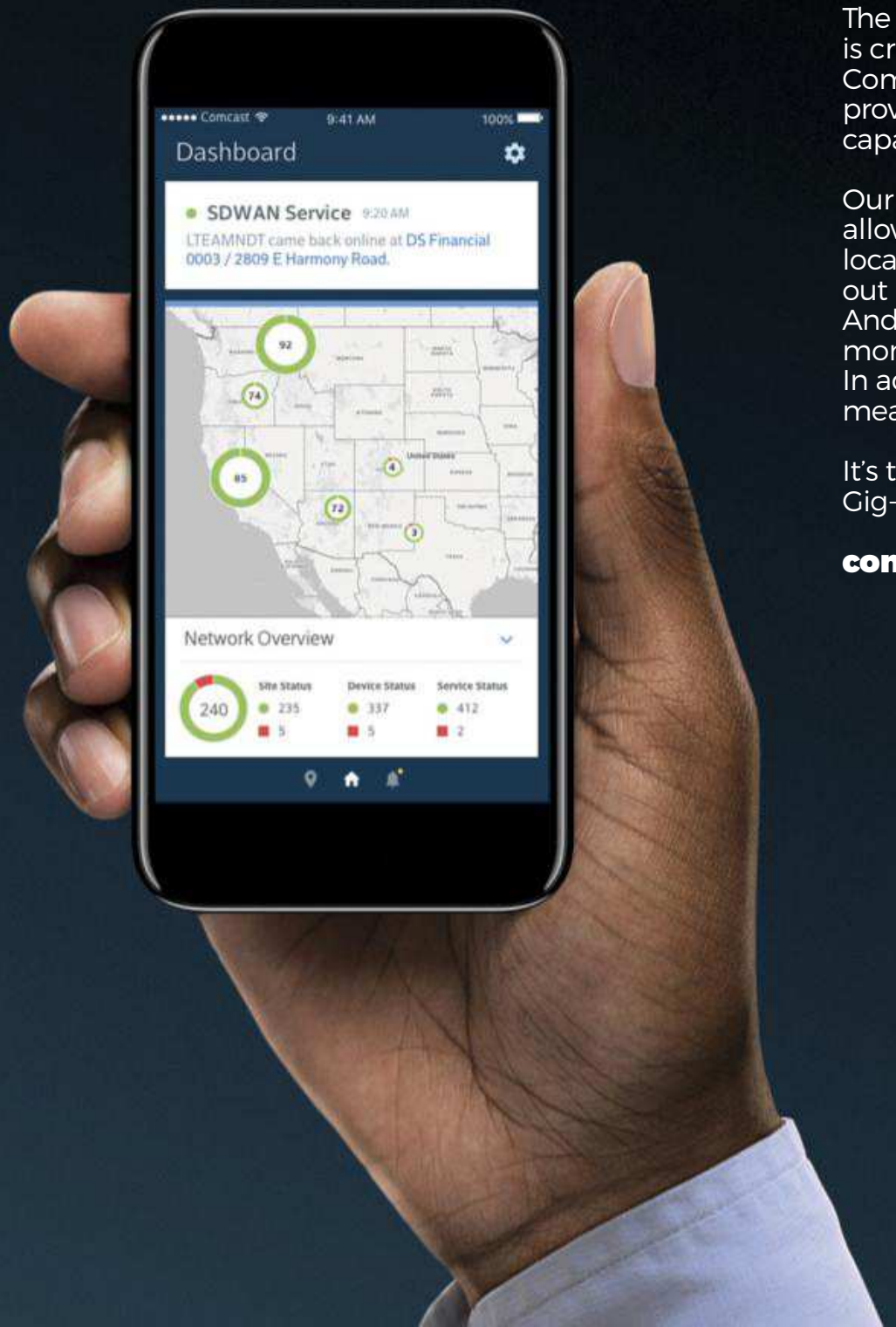
ANGRY NERD

TOO FAST, I'M FURIOUS

Like you—like every delirious commuter—I savor podcasts. They're a reprieve from my dead-eyed Twitter scroll. But unlike you, I don't stress about missing an episode or four. In fact, I find comfort in the medium's buffet of excess. Therefore I reserve special scorn for so-called *podfasters*: the tweakers who listen at 1.5X, 2X, even 3X speed. I see you over there—oblivious to the world, AirPods stuffed in your hearholes as, Joey Chestnut–style, you inhale *content*. Scads of apps aid you in this frantic endeavor. Rightspeed accelerates the pace every two minutes, turning Sarah Koenig's soothing timbre into a chittery titter, while Overcast algorithmically cleaves thoughtful pauses from conversations. Google's app offers no less than 16 speeds. My f-ing bike only has five! Listen to me, chipmunks—*listen*. Podcasting is an art, every choice subtle and intentional. You think Roman Mars exhales wistfully, just so, on a whim?! When you blow through an episode, you're gutting the experience of its hard-won nuance and cadence. Also, you're wrong: Speed-listeners *think* they're self-optimizing, but science shows comprehension flies off the rails at 2X—and crashes and burns at 3X. Ever wonder what happened to comfortable silences? Why small talk makes you want to pass out? Why the ring of your phone triggers a Pavlovian punching of the Ignore button? Blame the relentless babble that's blasting your brain to mush. —LAUREN MURROW

ANGRY NERD ILLUSTRATION BY ZOHAR LAZAR

A BUSINESS IS ONLY AS STRONG AS ITS WEAKEST LOCATION.



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OUTMANEUVER

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SLOW SOFTWARE
IN PRAISE OF FRICTION

ONLINE COMMERCE HAS made it easier than ever to shop, right? Maybe too easy. A recent study by comparison-shopping site Finder revealed that more than 88 percent of Americans admitted to spontaneous impulse buying online, blowing an average of $81.75 each time we lose control. Clothes, videogames, concert tickets. One in five of us succumb weekly. Millennials do it the most. ¶ "The main emotion that people feel after this impulsive spending is regret," says Jennifer McDermott, a consumer advocate for Finder. While it's not an impartial estimate, Finder calculates that we spend more than $17 billion on impulse buys—which is a lot of regret. ¶ So McDermott's team decided to help us rein in our impulses. They created Icebox, a Chrome plug-in that replaces the Buy button on 20 well-known ecommerce sites with a blue button labeled "Put it on ice." Hit it and your item goes into a queue, and a week or so later Icebox asks if you still want to buy it. ¶ In essence, it forces you to stop and ponder, "Do I really need this widget?" Odds are you don't. ¶ This is a lovely example of what I've come to think of as "friction engineering"—software that's designed not to speed us up but to slow us down. It's a principle that inverts everything we know about why software exists.

Most of the time coders labor to increase our throughput by reducing friction. Speed often improves life. But the recent techlash has been driven in a fundamental way by the grim side effects of this acceleration. Facebook's Newsfeed made it frictionlessly easy to spread misinformation; Twitter let trolls engage in coordinated harassment campaigns; Amazon enticed me to buy crap I manifestly don't need and is helping to denude towns of local businesses.

In contrast, inserting friction can bring intriguing wins. Consider the case of Nextdoor, the site that lets real-life neighbors create online hubs to talk to one another. The service includes a crime-reporting tool that made it easy to report suspicious activity. The problem was that jittery residents would too often write a racist alert whenever any black person so much as walked past their house.

So Nextdoor redesigned the crime-reporting tool to slow things down. Filing a report now requires listing specific details—what the suspicious person was wearing, their age, their actions. Using the tool suddenly involved more work. It helped: Nextdoor says racial profiling in its crime section dropped dramatically.

Others have tried to inject friction into the hummingbird metabolism of social media. Entrepreneur Andrew Golis created This, an app used to post only one link a day. "The goal," he tells me, was to encourage high-quality curation, "to create something that was like showing off your bookshelf, the things you really love."

What unifies these experiments is that they encourage deliberation. Why am I buying this? Why am I reporting this "suspicious" incident? Friction engineering ought to be taught in computer-science and design schools everywhere.

It's a Sisyphean battle, I admit. Offered the choice, we nearly always opt for convenience. Golis' This app died after less than two years of gathering only a small but devoted following; Icebox is brilliant but hasn't yet taken off. Socratic deliberation improves our lives—but, man, what a pain!

It's certainly possible to slow our software, and thereby ourselves. But it'll happen only when we become too unsettled by the speed of our journey.

Write to clive@clivethompson.net.

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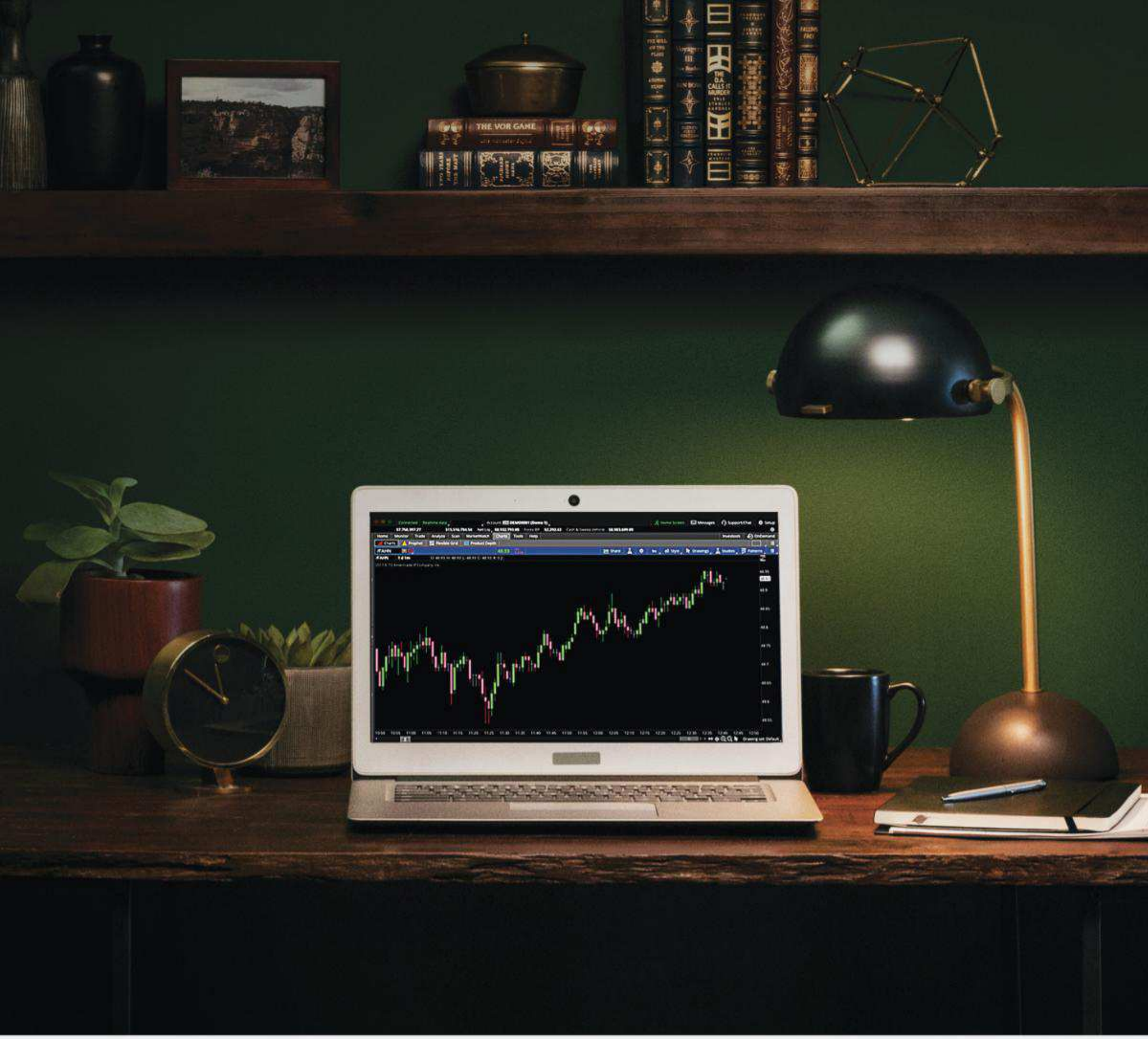

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IF YOU WANT YOUR KIDS to actually get excited about astronomy, don't fumble around with your telescope for 20 minutes while you try to locate Pegasus. BOR-ing. Leave the star-searching to this smartphone-connected scope from the French company Vaonis. The companion app streamlines heavenly gazing by precisely aiming the robotic telescope—at, say, Pegasus—in as little as a few seconds. The system uses Wi-Fi to display the live view on your phone, where it's easy to capture photographs and video, and it tracks the target across the sky long enough for everyone to get a look. The 19-inch-tall instrument is more portable than a traditional scope, so you can carry it into the wilderness where light pollution fades or just gaze at the constellations from your own backyard. —LYDIA HORNE

$2,999

STYLING BY KIKI STEVENS

KELSEY MCCLELLAN

HEAD-TO-HEAD RIDE-ALONGS

Park the SUV and instead chauffeur your helmeted children on an electric cargo bike. —ADRIENNE SO

Yuba Electric Boda Boda

BEST FOR: Elementary school drop-offs

This (relatively) affordable ebike comes with a nimble e6000 Shimano Steps system that offers three levels of assistance. The motor juices your pedal strokes only when needed and can last up to 93 miles, depending on how hard you work it. Optional grab bars and padded seat for the rear rack let your 6-year-old lean into the turns with you.

$3,499 and up

Riese & Müller Load

BEST FOR: Post-nap urban adventures

Strap two younger tots into the front box, clip panniers full of groceries on the rear rack, and glide home cushioned by front and rear suspension.

A dual-battery Bosch motor provides four assist modes and a range of over 100 miles. This 7-foot-long carry-all is a bit awkward in traffic, but you'll get used it by the weekend.

$7,399 and up

READY OR NOT, HERE WE COME.

Avalon

Play just got serious in the all-new Toyota Avalon.

Reboot the thrill of driving in Avalon Touring. Featuring available Sport+ Mode with Adaptive Variable Suspension (AVS), 19-in. sport wheels and daring new styling, Avalon pulls a complete 180 on the driving experience itself.

Let's Go Places.

toyota.com/**avalon**

1

1

Ryze Tech Tello

Kids can program this palm-sized drone to fly in wacky patterns or do tricks—somersaults!—using basic commands in Scratch, a child-friendly coding language. If they'd rather just use a controller to capture footage with the HD camera, a DJI-powered piloting system ensures safe, stable flights.

$99

2

Magical Microbes MudWatt

Your younglings can learn about electricity and get filthy at the same time. Fill the MudWatt with dirt from the backyard and ketchup from the fridge, then watch electrogenic microbes in action as they feast on sugars and expel electrons that light up the attached LED.

$40

2

PARENTING

GADGET LAB

GEARHEAD PLAY LIST

Keep your kids' neurons firing with these science- and math-centric toys and games. —JOSIE COLT

3

MoMA Design Store Colorful Backgammon Set

Backgammon has been helping kids (and adults) hone their math and problem-solving skills for millennia. This rainbow-hued set, encased in a gorgeous beechwood box, is a fun and elegant way to learn addition, subtraction, strategy, and probabilities.

$89

4

The Crafty Robot Smartibot

Paired with a smartphone, these DIY robots use object recognition to chase humans and pets around the house. When a bot's cardboard chassis gets worn, kids can fashion new bodies for the digital brains out of anything—Legos, carrots, or their own cardboard cutouts.

$55

5

Crayola Color Chemistry Lab Set

Melted crayons have long played a role in grade school science experiments. Now the Crayola folks make a proper chemistry set with 16 out-of-the-box projects and 34 more that use household ingredients, from erupting volcanoes and glow worms to three types of slime.

$25

TOP 3 NURSER'S AIDS

A new generation of breast pumps makes the task of collecting milk easier than ever. —ADRIENNE SO

1

Spectra S1Plus

Like the other pumps here, the S1Plus is a closed system—a barrier separates the pump and the collection components, discouraging bacterial growth. The 3-pound unit's rechargeable battery lasts a few days. You can adjust the vacuum strength and cycle frequency to optimize your pump sessions.

$200

2

Medela Sonata

The portable and rechargeable Sonata has soft buttons that you can push with a toe or elbow if your hands are full. It connects to your smartphone via Bluetooth, so you can use the MyMedela app to record the time and output of your sessions—and get 24-hour access to a lactation consultant.

$400

3

Freemie Liberty

Pump while working, driving home, or doing the dishes—no need to find a place where you can disrobe. The Liberty's cups slide discreetly under your clothes and into your bra, and the palm-sized, 8.8-ounce pump clips to your belt. The battery is good for as many as six 20-minute sessions between charges.

$300

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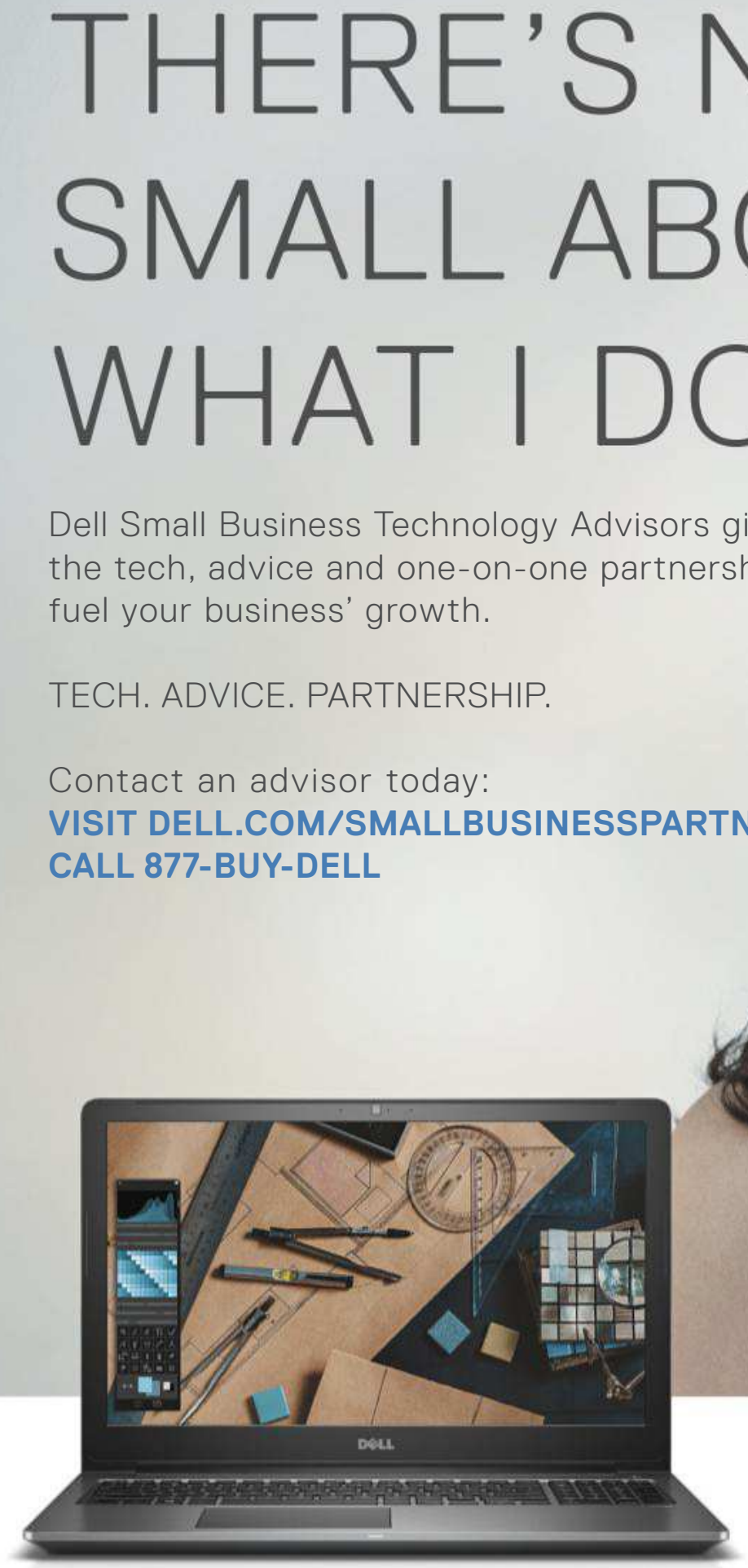

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intel CORE i3 inside

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BENCHMARK
CONNECT THE BLOCKS

▲

2x4 Brick $0.21

A Danish woodworker's bet on a new manufacturing process gave us the world's most famous brick. —JONATHON KEATS

WHEN OLE KIRK KRISTIANSEN imported a newfangled contraption called a plastic-injection-molding machine to Denmark in 1946, people thought he'd lost his mind. Kirk Kristiansen was a master carpenter who made wooden toys sold under the brand name Lego (abbreviated from *leg godt*, Danish for "play well"). The machine cost nearly 7 percent of the company's annual revenue, but Kirk Kristiansen reckoned there was no limit to what he could manufacture with the new technology. He could even redesign old-fashioned building blocks so that they wouldn't topple over. After making modest progress with interlocking indentations—a concept borrowed from another toy manufacturer—Ole's son, Godtfred, set to work on a mechanism for binding blocks together. After years of trial and error, he perfected the stud-and-tube coupling system that defines Lego to this day. The system required the molding process to be accurate to within 0.005 mm. Godtfred filed for a patent the year Ole died. Countless variations on the form followed over the decades—from roof tiles to Jedi weaponry—all of which can click with bricks from the Eisenhower era. Some 700 billion Lego pieces later, the result is a toy that never gets old.


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improperly stored gun, often found in the home.
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MIKE BLOOMBERG

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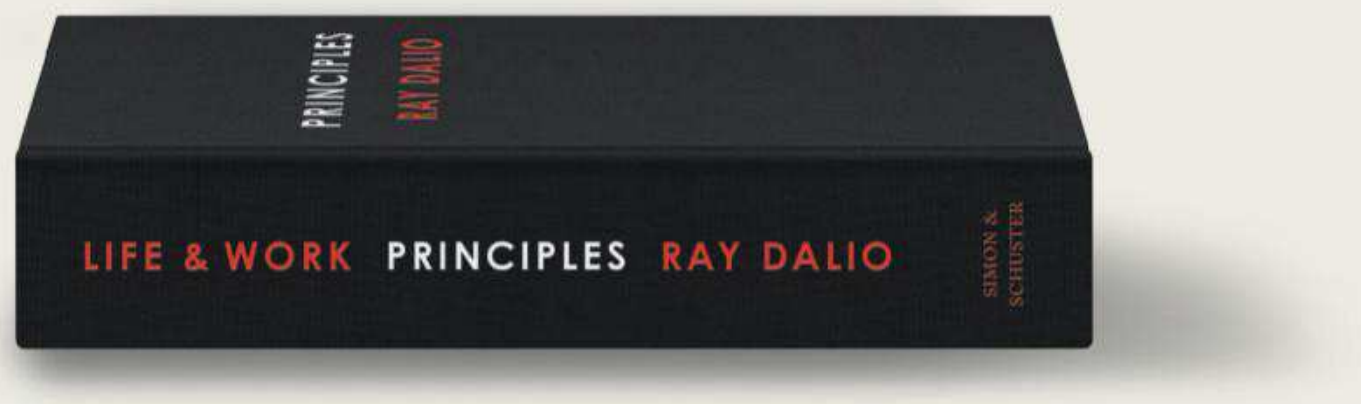

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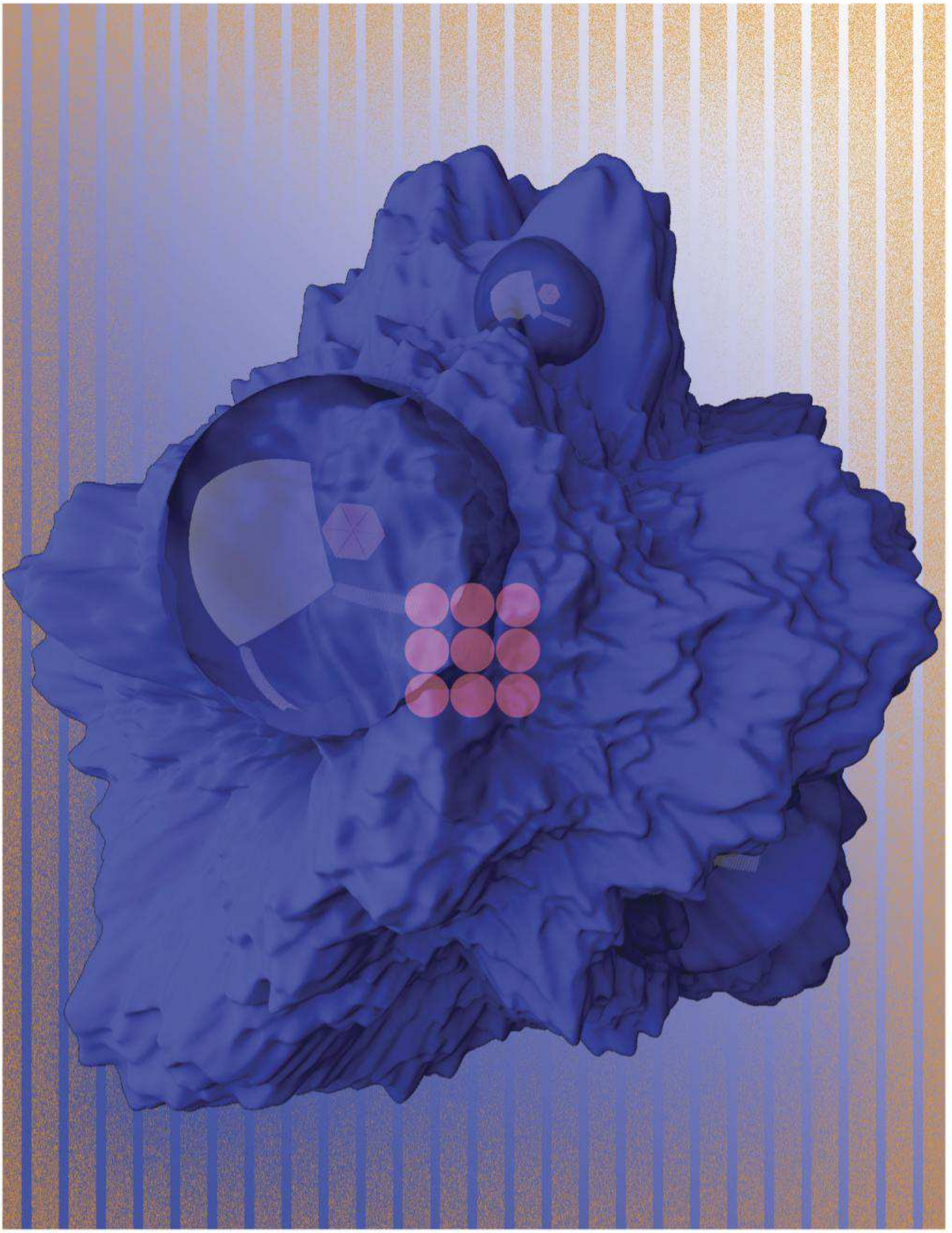

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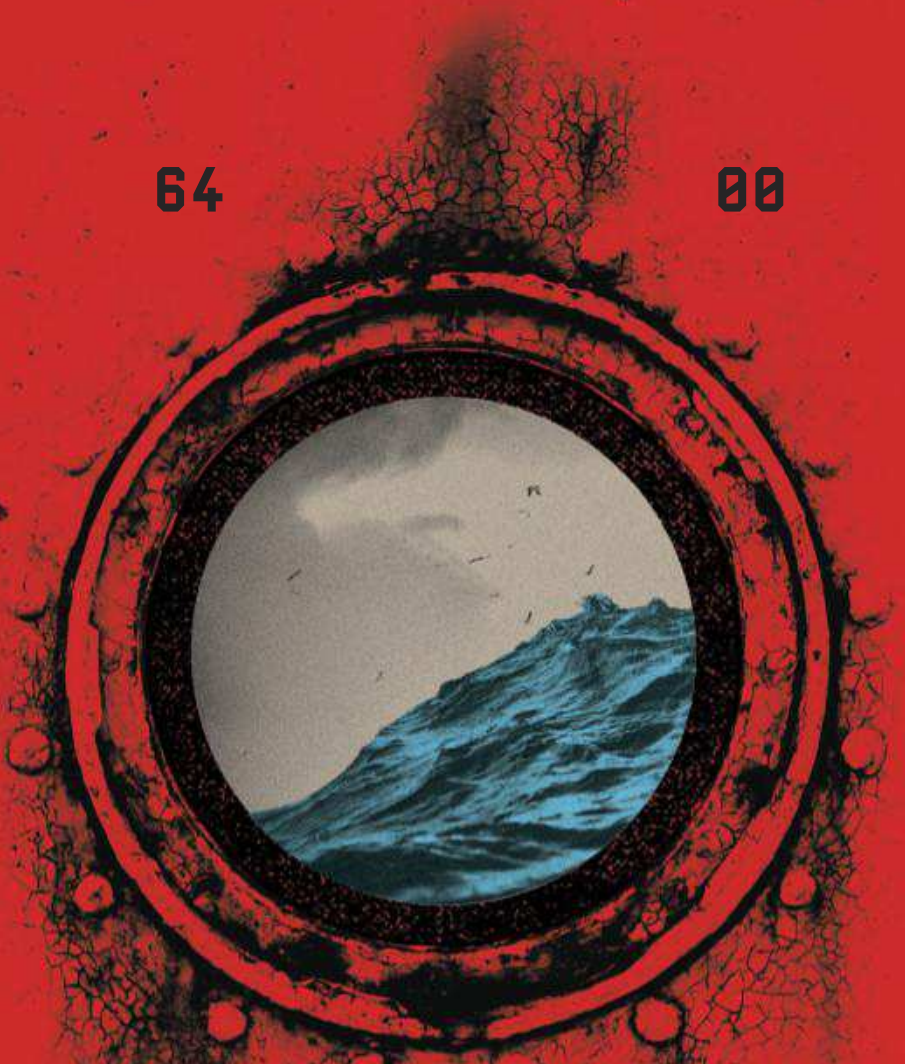

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CRIPPLED PORTS. PARALYZED CORPORATIONS. FROZEN GOVERNMENT AGENCIES. THE UNTOLD STORY OF NOTPETYA, THE MOST DEVASTATING CYBERATTACK IN HISTORY.

BY ANDY GREENBERG

It was a perfect sunny summer afternoon in Copenhagen when the world's largest shipping conglomerate began to lose its mind.

The headquarters of A.P. Møller-Maersk sits beside the breezy, cobblestoned esplanade of Copenhagen's harbor. A ship's mast carrying the Danish flag is planted by the building's northeastern corner, and six stories of blue-tinted windows look out over the water, facing a dock where the Danish royal family parks its yacht. In the building's basement, employees can browse a corporate gift shop, stocked with Maersk-branded bags and ties, and even a rare Lego model of the company's gargantuan Triple-E container ship, a vessel roughly as large as the Empire State Building laid on its side, capable of carrying another Empire State Building–sized load of cargo stacked on top of it.

That gift shop also houses a technology help center, a single desk manned by IT troubleshooters next to the shop's cashier. And on the afternoon of June 27, 2017, confused Maersk staffers began to gather at that help desk in twos and threes, almost all of them carrying laptops. On the machines' screens were messages in red and black lettering. Some read "repairing file system on C:" with a stark warning not to turn off the computer. Others, more surreally, read "oops, your important files are encrypted" and demanded a payment of $300 worth of bitcoin to decrypt them.

Across the street, an IT administrator named Henrik Jensen was working in another part of the Maersk compound, an ornate white-stone building that in previous centuries had served as the royal archive of maritime maps and charts. (Henrik Jensen is not his real name. Like almost every Maersk employee, customer, or partner I interviewed, Jensen feared the consequences of speaking publicly for this story.) Jensen was busy preparing a software update for Maersk's nearly 80,000 employees when his computer spontaneously restarted.

He quietly swore under his breath. Jensen assumed the unplanned reboot was a typically brusque move by Maersk's central IT department, a little-loved entity in England that oversaw most of the corporate empire, whose eight business units ranged from ports to logistics to oil drilling, in 574 offices in 130 countries around the globe.

Jensen looked up to ask if anyone else in his open-plan office of IT staffers had been so rudely interrupted. And as he craned his head, he watched every other computer screen around the room blink out in rapid succession.

"I saw a wave of screens turning black. Black, black, black. *Black black black black black*," he says. The PCs, Jensen and his neighbors quickly discovered, were irreversibly locked. Restarting only returned them to the same black screen.

All across Maersk headquarters, the full scale of the crisis was starting to become clear. Within half an hour, Maersk employees were running down hallways, yelling to their colleagues to turn off computers or disconnect them from Maersk's network

PREVIOUS PAGES PHOTO SOURCE: GETTY IMAGES

before the malicious software could infect them, as it dawned on them that every minute could mean dozens or hundreds more corrupted PCs. Tech workers ran into conference rooms and unplugged machines in the middle of meetings. Soon staffers were hurdling over locked key-card gates, which had been paralyzed by the still-mysterious malware, to spread the warning to other sections of the building.

Disconnecting Maersk's entire global network took the company's IT staff more than two panicky hours. By the end of that process, every employee had been ordered to turn off their computer and leave it at their desk. The digital phones at every cubicle, too, had been rendered useless in the emergency network shutdown.

Around 3 pm, a Maersk executive walked into the room where Jensen and a dozen or so of his colleagues were anxiously awaiting news and told them to go home. Maersk's network was so deeply corrupted that even IT staffers were helpless. A few of the company's more old-school managers told their teams to remain at the office. But many employees—rendered entirely idle without computers, servers, routers, or desk phones—simply left.

Jensen walked out of the building and into the warm air of a late June afternoon. Like the vast majority of Maersk staffers, he had no idea when he might return to work. The maritime giant that employed him, responsible for 76 ports on all sides of the earth and nearly 800 seafaring vessels, including container ships carrying tens of millions of tons of cargo, representing close to a fifth of the entire world's shipping capacity, was dead in the water.

On the edge of the trendy Podil neighborhood in the Ukrainian capital of Kiev, coffee shops and parks abruptly evaporate, replaced by a grim industrial landscape. Under a highway overpass, across some trash-strewn railroad tracks, and through a concrete gate stands the four-story headquarters of Linkos Group, a small, family-run Ukrainian software business.

Up three flights of stairs in that building is a server room, where a rack of pizza-box-sized computers is connected by a tangle of wires and marked with handwritten, numbered labels. On a normal day, these servers push out routine updates—bug fixes, security patches, new features—to a piece of accounting software called M.E.Doc, which is more or less Ukraine's equivalent of TurboTax or Quicken. It's used by nearly anyone who files taxes or does business in the country.

But for a moment in 2017, those machines served as ground zero for the most devastating cyberattack since the invention of the internet—an attack that began, at least, as an assault on one nation by another.

For the past four and a half years, Ukraine has been locked in a grinding, undeclared war with Russia that has killed more than 10,000 Ukrainians and displaced millions more. The conflict has also seen Ukraine become a scorched-earth testing ground for Russian cyberwar tactics. In 2015 and 2016, while the Kremlin-linked hackers known as Fancy Bear were busy breaking into the US Democratic National Committee's servers, another group of agents known as Sandworm was hacking into dozens of Ukrainian governmental organizations and companies. They penetrated the networks of victims ranging from media outlets to railway firms, detonating logic bombs that destroyed terabytes of data. The attacks followed a sadistic seasonal cadence. In the winters of both years, the saboteurs capped off their destructive sprees by causing widespread power outages—the first confirmed blackouts induced by hackers.

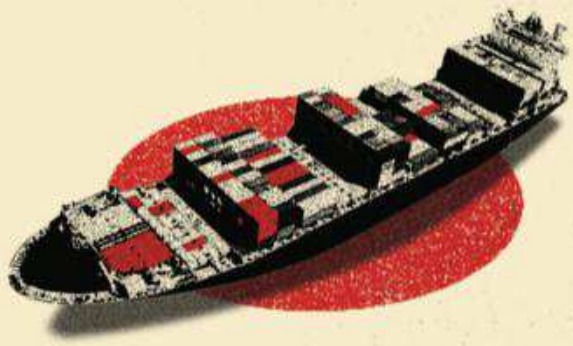
But those attacks still weren't Sandworm's grand finale. In the spring of 2017, unbeknownst to anyone at Linkos Group, Russian military hackers hijacked the company's update servers to allow them a hidden back door into the thousands of PCs around the country and the world that have M.E.Doc installed. Then, in June 2017, the saboteurs used that back door to release a piece of malware called NotPetya, their most vicious cyberweapon yet.

The code that the hackers pushed out was honed to spread automatically, rapidly, and indiscriminately. "To date, it was simply the fastest-propagating piece of malware we've ever seen," says Craig Williams, director of outreach at Cisco's Talos division, one of the first security companies to reverse engineer and analyze NotPetya. "By the second you saw it, your data center was already gone."

NotPetya was propelled by two powerful hacker exploits working in tandem: One was a penetration tool known as EternalBlue, created by the US National Security Agency but leaked in a disastrous breach of the agency's ultrasecret files earlier in

ILLUSTRATIONS BY MIKE MCQUADE

ANDY GREENBERG *(@a_greenberg) is a* WIRED *senior writer. This story is excerpted from his book* Sandworm, *forthcoming from Doubleday.*



THE WEAPON'S TARGET WAS UKRAINE. BUT ITS BLAST RADIUS WAS THE ENTIRE WORLD.

"IT WAS THE EQUIVALENT OF USING A NUCLEAR BOMB TO ACHIEVE A SMALL TACTICAL VICTORY," BOSSERT SAYS.

2017. EternalBlue takes advantage of a vulnerability in a particular Windows protocol, allowing hackers free rein to remotely run their own code on any unpatched machine.

NotPetya's architects combined that digital skeleton key with an older invention known as Mimikatz, created as a proof of concept by French security researcher Benjamin Delpy in 2011. Delpy had originally released Mimikatz to demonstrate that Windows left users' passwords lingering in computers' memory. Once hackers gained initial access to a computer, Mimikatz could pull those passwords out of RAM and use them to hack into other machines accessible with the same credentials. On networks with multiuser computers, it could even allow an automated attack to hopscotch from one machine to the next.

Before NotPetya's launch, Microsoft had released a patch for its EternalBlue vulnerability. But EternalBlue and Mimikatz together nonetheless made a virulent combination. "You can infect computers that aren't patched, and then you can grab the passwords from those computers to infect other computers that *are* patched," Delpy says.

NotPetya took its name from its resemblance to the ransomware Petya, a piece of criminal code that surfaced in early 2016 and extorted victims to pay for a key to unlock their files. But NotPetya's ransom messages were only a ruse: The malware's goal was purely destructive. It irreversibly encrypted computers' master boot records, the deep-seated part of a machine that tells it where to find its own operating system. Any ransom payment that victims tried to make was futile. No key even existed to reorder the scrambled noise of their computer's contents.

The release of NotPetya was an act of cyberwar by almost any definition—one that was likely more explosive than even its creators intended. Within hours of its first appearance, the worm raced beyond Ukraine and out to countless machines around the world, from hospitals in Pennsylvania to a chocolate factory in Tasmania. It crippled multinational companies including Maersk, pharmaceutical giant Merck, FedEx's European subsidiary TNT Express, French construction company Saint-Gobain, food producer Mondelēz, and manufacturer Reckitt Benckiser. In each case, it inflicted nine-figure costs. It even spread back to Russia, striking the state oil company Rosneft.

The result was more than $10 billion in total damages, according to a White House assessment confirmed to WIRED by former Homeland Security adviser Tom Bossert, who at the time of the attack was President Trump's most senior cybersecurity-focused official. Bossert and US intelligence agencies also confirmed in February that Russia's military—the prime suspect in any cyberwar attack targeting Ukraine—was responsible for launching the malicious code. (The Russian foreign ministry declined to answer repeated requests for comment.)

To get a sense of the scale of NotPetya's damage, consider the nightmarish but more typical ransomware attack that paralyzed the city government of Atlanta this past March: It cost up to $10 million, a tenth of a percent of NotPetya's price. Even WannaCry, the more notorious worm that spread a month before NotPetya in May 2017, is estimated to have cost between $4 billion and $8 billion. Nothing since has come close. "While there was no loss of life, it was the equivalent of using a nuclear bomb to achieve a small tactical victory," Bossert says. "That's a degree of recklessness we can't tolerate on the world stage."

In the year since NotPetya shook the world, WIRED has delved into the experience of one corporate goliath brought to its knees by Russia's worm: Maersk, whose malware fiasco uniquely demonstrates the danger that cyberwar now poses to the infrastructure of the modern world. The executives of the shipping behemoth, like every other non-Ukrainian victim WIRED approached to speak about NotPetya, declined to comment in any official capacity for this story. WIRED's account is instead assembled from current and former Maersk sources, many of whom chose to remain anonymous.

But the story of NotPetya isn't truly about

Maersk, or even about Ukraine. It's the story of a nation-state's weapon of war released in a medium where national borders have no meaning, and where collateral damage travels via a cruel and unexpected logic: Where an attack aimed at Ukraine strikes Maersk, and an attack on Maersk strikes everywhere at once.

Oleksii Yasinsky expected a calm Tuesday at the office. It was the day before Ukraine's Constitution Day, a national holiday, and most of his coworkers were either planning their vacations or already taking them. But not Yasinsky. For the past year he'd been the head of the cyber lab at Information Systems Security Partners, a company that was quickly becoming the go-to firm for victims of Ukraine's cyberwar. That job description didn't lend itself to downtime. Since the first blows of Russia's cyberattacks hit in late 2015, in fact, he'd allowed himself a grand total of one week off.

So Yasinsky was unperturbed when he received a call that morning from ISSP's director telling him that Oschadbank, the second-largest bank in Ukraine, was under attack. The bank had told ISSP that it was facing a ransomware infection, an increasingly common crisis for companies around the world targeted by profit-focused cybercriminals. But when Yasinsky walked into Oschadbank's IT department at its central Kiev office half an hour later, he could tell this was something new. "The staff were lost, confused, in a state of shock," Yasinsky says. Around 90 percent of the bank's thousands of computers were locked, showing NotPetya's "repairing disk" messages and ransom screens.

After a quick examination of the bank's surviving logs, Yasinsky could see that the attack was an automated worm that had somehow obtained an administrator's credentials. That had allowed it to rampage through the bank's network like a prison inmate who has stolen the warden's keys.

As he analyzed the bank's breach back in ISSP's office, Yasinsky started receiving calls and messages from people around Ukraine, telling him of similar instances in other companies and government agencies. One told him that another victim had attempted to pay the ransom. As Yasinsky suspected, the payment had no effect. This was no ordinary ransomware. "There was no silver bullet for this, no antidote," he says.

A thousand miles to the south, ISSP CEO Roman Sologub was attempting to take a Constitution Day vacation on the southern coast of Turkey, preparing to head to the beach with his family. His phone, too, began to explode with calls from ISSP clients who were either watching NotPetya tear across their networks or reading news of the attack and frantically seeking advice.

Sologub retreated to his hotel, where he'd spend the rest of the day fielding more than 50 calls from customers reporting, one after another after another, that their networks had been infected. ISSP's security operations center, which monitored the networks of clients in real time, warned Sologub that NotPetya was saturating victims' systems with terrifying speed: It took 45 seconds to bring down the network of a large Ukrainian bank. A portion of one major Ukrainian transit hub, where ISSP had installed its equipment as a demonstration, was fully infected in 16 seconds. Ukrenergo, the energy company whose network ISSP had been helping to rebuild after the 2016 blackout cyberattack, had also been struck yet again. "Do you remember we were about to implement new security controls?" Sologub recalls a frustrated Ukrenergo IT director asking him on the phone. "Well, too late."

By noon, ISSP's founder, a serial entrepreneur named Oleh Derevianko, had sidelined his vacation too. Derevianko was driving north to meet his family at his village house for the holiday when the NotPetya calls began. Soon he had pulled off the highway and was working from a roadside restaurant. By the early afternoon, he was warning every executive who called to unplug their networks without hesitation, even if it meant shutting down their entire company. In many cases, they'd already waited too long. "By the time you reached them, the infrastructure was already lost," Derevianko says.

On a national scale, NotPetya was eating Ukraine's computers alive. It would hit at least four hospitals in Kiev alone, six power companies, two airports, more than 22 Ukrainian banks, ATMs and card payment systems in retailers and transport, and practically every federal agency. "The government was dead," summarizes Ukrainian minister of infrastructure Volodymyr Omelyan. According to ISSP, at least 300 companies were hit, and one senior Ukrainian government official estimated that 10 percent of all computers in the country were wiped. The attack even shut down the computers used by scientists at the Chernobyl cleanup site, 60 miles north of Kiev. "It was a massive bombing of all our systems," Omelyan says.

THE COST OF NOTPETYA

In 2017, the malware NotPetya spread from the servers of an unassuming Ukrainian software firm to some of the largest businesses worldwide, paralyzing their operations. Here's a list of the approximate damages reported by some of the worm's biggest victims.

$870,000,000
Pharmaceutical company Merck

$400,000,000
Delivery company FedEx
(through European subsidiary TNT Express)

$384,000,000
French construction company Saint-Gobain

$300,000,000
Danish shipping company Maersk

$188,000,000
Snack company Mondelēz
(parent company of Nabisco and Cadbury)

$129,000,000
British manufacturer Reckitt Benckiser
(owner of Lysol and Durex condoms)

$10 BILLION
Total damages from NotPetya, as estimated by the White House

When Derevianko emerged from the restaurant in the early evening, he stopped to refuel his car and found that the gas station's credit card payment system had been taken out by NotPetya too. With no cash in his pockets, he eyed his gas gauge, wondering if he had enough fuel to reach his village. Across the country, Ukrainians were asking themselves similar questions: whether they had enough money for groceries and gas to last through the blitz, whether they would receive their paychecks and pensions, whether their prescriptions would be filled. By that night, as the outside world was still debating whether NotPetya was criminal ransomware or a weapon of state-sponsored cyberwar, ISSP's staff had already started referring to it as a new kind of phenomenon: a "massive, coordinated cyber invasion."

Amid that epidemic, one single infection would become particularly fateful for Maersk: In an office in Odessa, a port city on Ukraine's Black Sea coast, a finance executive for Maersk's Ukraine operation had asked IT administrators to install the accounting software M.E.Doc on a single computer. That gave NotPetya the only foothold it needed.

The shipping terminal in Elizabeth, New Jersey—one of the 76 that make up the port-operations division of Maersk known as APM Terminals—sprawls out into Newark Bay on a man-made peninsula covering a full square mile. Tens of thousands of stacked, perfectly modular shipping containers cover its vast asphalt landscape, and 200-foot-high blue cranes loom over the bay. From the top floors of lower Manhattan's skyscrapers, five miles away, they look like brachiosaurs gathered at a Jurassic-era watering hole.

On a good day, about 3,000 trucks arrive at the terminal, each assigned to pick up or drop off tens of thousands of pounds of everything from diapers to avocados to tractor parts. They start that process, much like airline passengers, by checking in at the terminal's gate, where scanners automatically read their container's barcodes and a Maersk gate clerk talks to the truck driver via a speaker system. The driver receives a printed pass that tells them where to park so that a massive yard crane can haul their container from the truck's chassis to a stack in the cargo yard, where it's loaded onto a container ship and floated across an ocean—or that entire process in reverse order.

On the morning of June 27, Pablo Fernández was expecting dozens of trucks' worth of cargo to be shipped out from Elizabeth to a port in the Middle East. Fernández is a so-called freight forwarder—a middleman whom cargo owners pay to make sure their property arrives safely at a destination halfway around the world. (Fernández is not his real name.)

At around 9 am New Jersey time, Fernández's phone started buzzing with a succession of screaming calls from angry cargo owners. All of them had just heard from truck drivers that their vehicles were stuck outside Maersk's Elizabeth terminal. "People were jumping up and down," Fernández says. "They couldn't get their containers in and out of the gate."

That gate, a choke point to Maersk's entire New Jersey terminal operation, was dead. The gate clerks had gone silent.

Soon, hundreds of 18-wheelers were backed up in a line that stretched for miles outside the terminal. One employee at another company's nearby terminal at the same New Jersey port watched the trucks collect, bumper to bumper, farther than he could see. He'd seen gate systems go down for stretches of 15 minutes or half an hour before. But after a few hours, still with no word from Maersk, the Port Authority put out an alert that the company's Elizabeth terminal would be closed for the rest of the day. "That's when we started to realize," the nearby terminal's staffer remembers, "this was an attack." Police began to approach drivers in their cabs, telling them to turn their massive loads around and clear out.

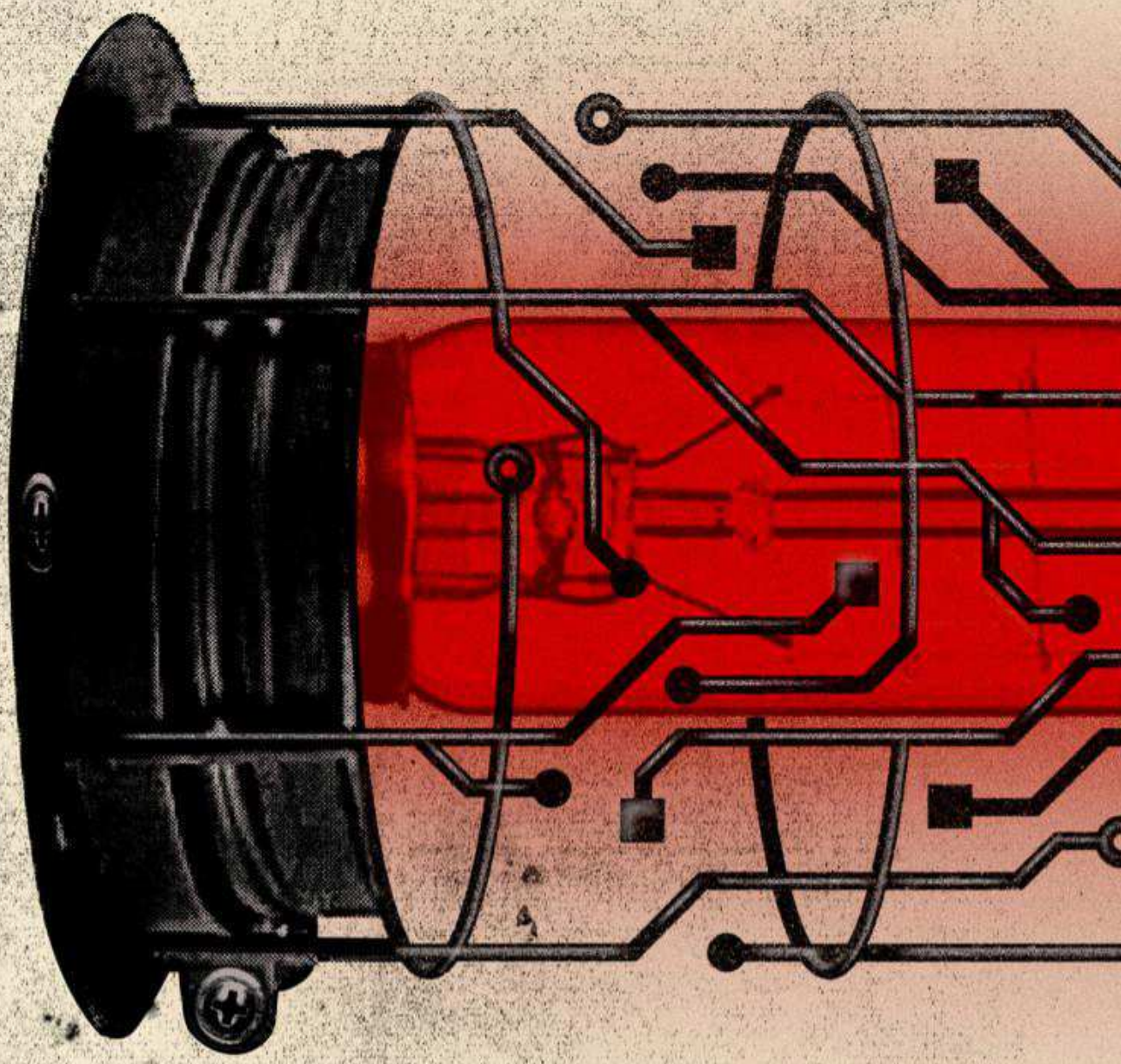
Fernández and countless other frantic Maersk customers faced a set of bleak options: They could try to get their precious cargo onto other ships at premium, last-minute rates, often traveling the equivalent of standby. Or, if their cargo was part of a tight supply chain, like components for a factory, Maersk's outage could mean shelling out for exorbitant air freight delivery or risk stalling manufacturing processes, where a single day of downtime costs hundreds of thousands of dollars. Many of the containers, known as reefers, were electrified and full of perishable goods that required refrigeration. They'd have to be plugged in somewhere or their contents would rot.

Fernández had to scramble to find a New Jersey warehouse where he could stash his customers' cargo while he waited for word from Maersk. During the entire first day, he says, he received only one official email, which read like "gibberish," from a frazzled Maersk staffer's Gmail account, offering no real explanation of the mounting crisis. The company's central booking website, Maerskline.com, was down, and no one at the company was picking up their phones. Some of the containers he'd sent on Maersk's ships that day would remain lost in cargo yards and ports around the world for the next three months. "Maersk was like a black hole," Fernández remembers with a sigh. "It was just a clusterfuck."

In fact, it was a clusterfuck of clusterfucks. The same scene was playing out at 17 of Maersk's 76 terminals, from Los Angeles to Algeciras, Spain, to Rotterdam in the Netherlands, to Mumbai. Gates were down. Cranes were frozen. Tens of thousands of trucks would be turned away from comatose terminals across the globe.

No new bookings could be made, essentially cutting off Maersk's core source of shipping revenue. The computers on Maersk's ships weren't infected. But the terminals' software, designed to receive the Electronic Data Interchange files from those ships, which tell terminal operators the exact contents of their massive cargo holds, had been entirely wiped away. That left Maersk's ports with no guide to perform the colossal Jenga game of loading and unloading their towering piles of containers.

For days to come, one of the world's most complex and interconnected distributed machines, underpinning the circulatory system of the global economy itself, would remain broken. "It was clear this problem was of a magnitude never seen before in global transport," one Maersk customer remembers. "In the history of shipping IT, no one has ever gone through such a monumental crisis."



Several days after his screen had gone dark in a corner of Maersk's office, Henrik Jensen was at home in his Copenhagen apartment, enjoying a brunch of poached eggs, toast, and marmalade. Since he'd walked out of the office the Tuesday before, he hadn't heard a word from any of his superiors. Then his phone rang.

When he answered, he found himself on a conference call with three Maersk staffers. He was needed, they said, at Maersk's office in Maidenhead, England, a town west of London where the conglomerate's IT overlords, Maersk Group Infrastructure Services, were based. They told him to drop everything and go there. Immediately.

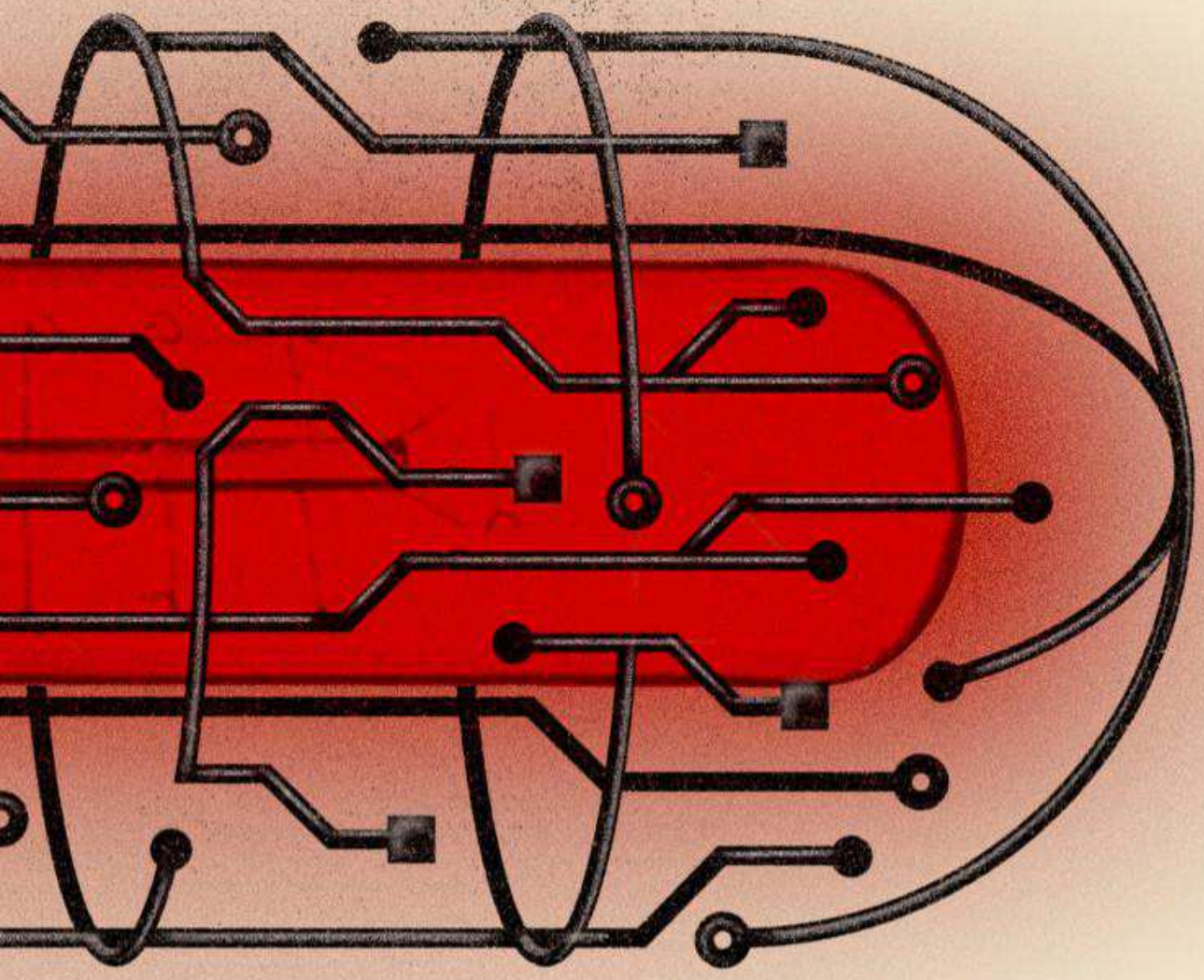
Two hours later, Jensen was on a plane to London, then in a car to an eight-story glass-and-brick building in central Maidenhead. When he arrived, he found that the fourth and fifth floors of the building had been converted into a 24/7 emergency operations center. Its singular purpose: to rebuild Maersk's global network in the wake of its NotPetya meltdown.

Some Maersk staffers, Jensen learned, had been in the recovery center since Tuesday, when NotPetya first struck. Some had been sleeping in the office, under their desks or in corners of conference rooms. Others seemed to be arriving every minute from other parts of the world, luggage in hand. Maersk had booked practically every hotel room within tens of miles, every bed-and-breakfast, every spare room above a pub. Staffers were subsisting on snacks that someone had piled up in the office kitchen after a trip to a nearby Sainsbury's grocery store.

The Maidenhead recovery center was being managed by the consultancy Deloitte. Maersk had essentially given the UK firm a blank check to make its NotPetya problem go away, and at any given time as many as 200 Deloitte staffers were stationed in the Maidenhead office, alongside up to 400 Maersk personnel. All computer equipment used by Maersk from before NotPetya's outbreak had been confiscated, for fear that it might infect new systems, and signs were posted threatening disciplinary action against anyone who used it. Instead, staffers had gone into every available electronics store in Maidenhead and bought up piles of new laptops and prepaid Wi-Fi hot spots. Jensen, like hundreds of other Maersk IT staffers, was given one of those fresh laptops and told to do his job. "It was very much just 'Find your corner, get to work, do whatever needs to be done,'" he says.

Early in the operation, the IT staffers rebuilding Maersk's network came to a sickening realization. They had located backups of almost all of Maersk's individual servers, dating from between three and seven days prior to NotPetya's onset. But no one could find a backup for one crucial layer of the company's network: its domain controllers, the servers that function as a detailed map of Maersk's network and set the basic rules that determine which users are allowed access to which systems.

Maersk's 150 or so domain controllers were programmed to sync their data with one another, so that, in theory, any of them could function as a backup for all the others. But that decentralized backup strategy



hadn't accounted for one scenario: where every domain controller is wiped simultaneously. "If we can't recover our domain controllers," a Maersk IT staffer remembers thinking, "we can't recover anything."

After a frantic search that entailed calling hundreds of IT admins in data centers around the world, Maersk's desperate administrators finally found one lone surviving domain controller in a remote office—in Ghana. At some point before NotPetya struck, a blackout had knocked the Ghanaian machine offline, and the computer remained disconnected from the network. It thus contained the singular known copy of the company's domain controller data left untouched by the malware—all thanks to a power outage. "There were a lot of joyous whoops in the office when we found it," a Maersk administrator says.

When the tense engineers in Maidenhead set up a connection to the Ghana office, however, they found its bandwidth was so thin that it would take days to transmit the several-hundred-gigabyte domain controller backup to the UK. Their next idea: put a Ghanaian staffer on the next plane to London. But none of the West African office's employees had a British visa.

So the Maidenhead operation arranged for a kind of relay race: One staffer from the Ghana office flew to Nigeria to meet another Maersk employee in the airport to hand off the very precious hard drive. That staffer then boarded the six-and-a-half-hour flight to Heathrow, carrying the keystone of Maersk's entire recovery process.

With that rescue operation completed, the Maidenhead office could begin bringing Maersk's core services back online. After the first days, Maersk's port operations had regained the ability to read the ships' inventory files, so operators were no longer blind to the contents of the hulking, 18,000-container vessels arriving in their harbors. But several days would pass after the initial outage before Maersk started taking orders through Maerskline.com for new shipments, and it would be more than a week before terminals around the world started functioning with any degree of normalcy.

In the meantime, Maersk staffers worked with whatever tools were still available to them. They taped paper documents to shipping containers at APM ports and took orders via personal Gmail accounts, WhatsApp, and Excel spreadsheets. "I can tell you it's a fairly bizarre experience to find yourself booking 500 shipping containers via WhatsApp, but that's what we did," one Maersk customer says.

About two weeks after the attack, Maersk's network had finally reached a point where the company could begin reissuing personal computers to the majority of staff. Back at the Copenhagen headquarters, a cafeteria in the basement of the building was turned into a reinstallation assembly line. Computers were lined up 20 at a time on dining tables as help desk staff walked down the rows, inserting USB drives they'd copied by the dozens, clicking through prompts for hours.

A few days after his return from Maidenhead, Henrik Jensen found his laptop in an alphabetized pile of hundreds, its hard drive wiped, a clean image of Windows

AFTER A FRANTIC GLOBAL SEARCH, THE ADMINS FINALLY FOUND ONE LONE SURVIVING DOMAIN CONTROLLER IN A REMOTE OFFICE—IN GHANA.

installed. Everything that he and every other Maersk employee had stored locally on their machines, from notes to contacts to family photos, was gone.

Five months after Maersk had recovered from its NotPetya attack, Maersk chair Jim Hagemann Snabe sat onstage at the World Economic Forum meeting in Davos, Switzerland, and lauded the "heroic effort" that went into the company's IT rescue operation. From June 27, when he was first awakened by a 4 am phone call in California, ahead of a planned appearance at a Stanford conference, he said, it took just 10 days for the company to rebuild its entire network of 4,000 servers and 45,000 PCs. (Full recovery had taken far longer: Some staffers at the Maidenhead operation continued to work day and night for close to two months to rebuild Maersk's software setup.) "We overcame the problem with human resilience," Snabe told the crowd.

Since then, Snabe went on, Maersk has worked not only to improve its cybersecurity but also to make it a "competitive advantage." Indeed, in the wake of NotPetya, IT staffers say that practically every security feature they've asked for has been almost immediately approved. Multifactor authentication has been rolled out across the company, along with a long-delayed upgrade to Windows 10.

Snabe, however, didn't say much about the company's security posture pre-NotPetya. Maersk security staffers tell WIRED that some of the corporation's servers were, up until the attack, still running Windows 2000—an operating system so old Microsoft no longer supported it. In 2016, one group of IT executives had pushed for a preemptive security redesign of Maersk's entire global network. They called attention to Maersk's less-than-perfect software patching, outdated operating systems, and above all insufficient network segmentation. That last vulnerability in particular, they warned, could allow malware with access to one part of the network to spread wildly beyond its initial foothold, exactly as NotPetya would the next year.

The security revamp was green-lit and budgeted. But its success was never made a so-called key performance indicator for Maersk's most senior IT overseers, so implementing it wouldn't contribute to their bonuses. They never carried the security makeover forward.

Few firms have paid more dearly for dragging their feet on security. In his Davos talk, Snabe claimed that the company suffered only a 20 percent reduction in total shipping volume during its NotPetya outage, thanks to its quick efforts and manual workarounds. But aside from the company's lost business and downtime, as well as the cost of rebuilding an entire network, Maersk also reimbursed many of its customers for the expense of rerouting or storing their marooned cargo. One Maersk customer described receiving a seven-figure check from the company to cover the cost of sending his cargo via last-minute chartered jet. "They paid me a cool million with no more than a two-minute discussion," he says.

All told, Snabe estimated in his Davos comments, NotPetya cost Maersk between $250 million and $300 million. Most of the staffers WIRED spoke with privately suspected the company's accountants had low-balled the figure.

Regardless, those numbers only start to describe the magnitude of the damage. Logistics companies whose livelihoods depend on Maersk-owned terminals weren't all treated as well during the outage as Maersk's customers, for instance. Jeffrey Bader, president of a Port Newark–based trucking group, the Association of Bi-State Motor Carriers, estimates that the unreimbursed cost for trucking companies and truckers alone is in the tens of millions. "It was a nightmare," Bader says. "We lost a lot of money, and we're angry."

The wider cost of Maersk's disruption to the global supply chain as a whole—which depends on just-in-time delivery of products and manufacturing components—is far harder to measure. And, of course, Maersk was only one victim. Merck, whose ability to manufacture some drugs was temporarily shut down by NotPetya, told shareholders it lost a staggering $870 million due to the malware. FedEx, whose European subsidiary TNT Express was crippled in the attack and required months to recover some data, took a $400 million blow. French construction giant Saint-Gobain lost around the same amount. Reckitt Benckiser, the British manufacturer of Durex condoms, lost $129 million, and Mondelēz, the owner of chocolate-maker Cadbury, took a $188 million hit. Untold numbers of victims without public shareholders counted their losses in secret.

Only when you start to multiply Maersk's story—imagining the same paralysis, the same serial crises, the same grueling recovery—playing out across dozens of other NotPetya victims and countless other industries does the true scale of Russia's cyberwar crime begin to come into focus.

"This was a very significant wake-up call," Snabe said at his Davos panel. Then he added, with a Scandinavian touch of understatement, "You could say, a very expensive one."

One week after NotPetya's outbreak, Ukrainian police dressed in full SWAT camo gear and armed with assault rifles poured out of vans and into the modest headquarters of Linkos Group, running up the stairs like SEAL Team Six invading the bin Laden compound.

They pointed rifles at perplexed employees and lined them up in the hallway, according to the company's founder, Olesya Linnyk. On the second floor, next to her office, the armored cops even smashed open the door to one room with a metal baton, in spite of Linnyk's offer of a key to unlock it. "It was an absurd situation," Linnyk says after a deep breath of exasperation.

The militarized police squad finally found what it was looking for: the rack of servers that had played the role of patient zero in the NotPetya plague. They confiscated the offending machines and put them in plastic bags.

Even now, more than a year after the attack's calamitous spread, cybersecurity experts still argue over the mysteries of NotPetya. What were the hackers' true intentions? The Kiev staff of security firm ISSP, including Oleh Derevianko and Oleksii Yasinsky, maintain that the attack was intended not merely for destruction but as a cleanup effort. After all, the hackers who launched it first had months of unfettered access to victims' networks. On top of the panic and disruption it caused, NotPetya may have also wiped away evidence of espionage or even reconnaissance for future sabotage. Just in May, the US Justice Department and Ukrainian security services announced that they'd disrupted a Russian operation that had infected half a million internet routers—mostly in Ukraine—with a new form of destructive malware.

While many in the security community still see NotPetya's international victims as collateral damage, Cisco's Craig Williams argues that Russia knew full well the extent of the pain the worm would inflict internationally. That fallout, he argues, was meant to explicitly punish anyone who would dare even to maintain an office inside the borders of Russia's enemy. "Anyone who thinks this was accidental is engaged in wishful thinking," Williams says. "This was a piece of malware designed to send a political message: If you do business in Ukraine, bad things are going to happen to you."

Almost everyone who has studied NotPetya, however, agrees on one point: that it could happen again or even reoccur on a larger scale. Global corporations are simply too interconnected, information security too complex, attack surfaces too broad to protect against state-trained hackers bent on releasing the next world-shaking worm. Russia, meanwhile, hardly seems to have been chastened by the US government's sanctions for NotPetya, which arrived a full eight months after the worm hit and whose punishments were muddled with other messages chastising Russia for everything from 2016 election disinformation to hacker probes of the US power grid. "The lack of a proper response has been almost an invitation to escalate more," says Thomas Rid, a political science professor at Johns Hopkins' School of Advanced International Studies.

But the most enduring object lesson of NotPetya may simply be the strange, extradimensional landscape of cyberwar's battlefield. This is the confounding geography of cyberwarfare: In ways that still defy human intuition, phantoms inside M.E.Doc's server room in a gritty corner of Kiev spread chaos into the gilded conference rooms of the capital's federal agencies, into ports dotting the globe, into the stately headquarters of Maersk on the Copenhagen harbor, and across the global economy. "Somehow the vulnerability of this Ukrainian accounting software affects the US national security supply of vaccines and global shipping?" asks Joshua Corman, a cybersecurity fellow at the Atlantic Council, as if still puzzling out the shape of the wormhole that made that cause-and-effect possible. "The physics of cyberspace are wholly different from every other war domain."

In those physics, NotPetya reminds us, distance is no defense. Every barbarian is already at every gate. And the network of entanglements in that ether, which have unified and elevated the world for the past 25 years, can, over a few hours on a summer day, bring it to a crashing halt.

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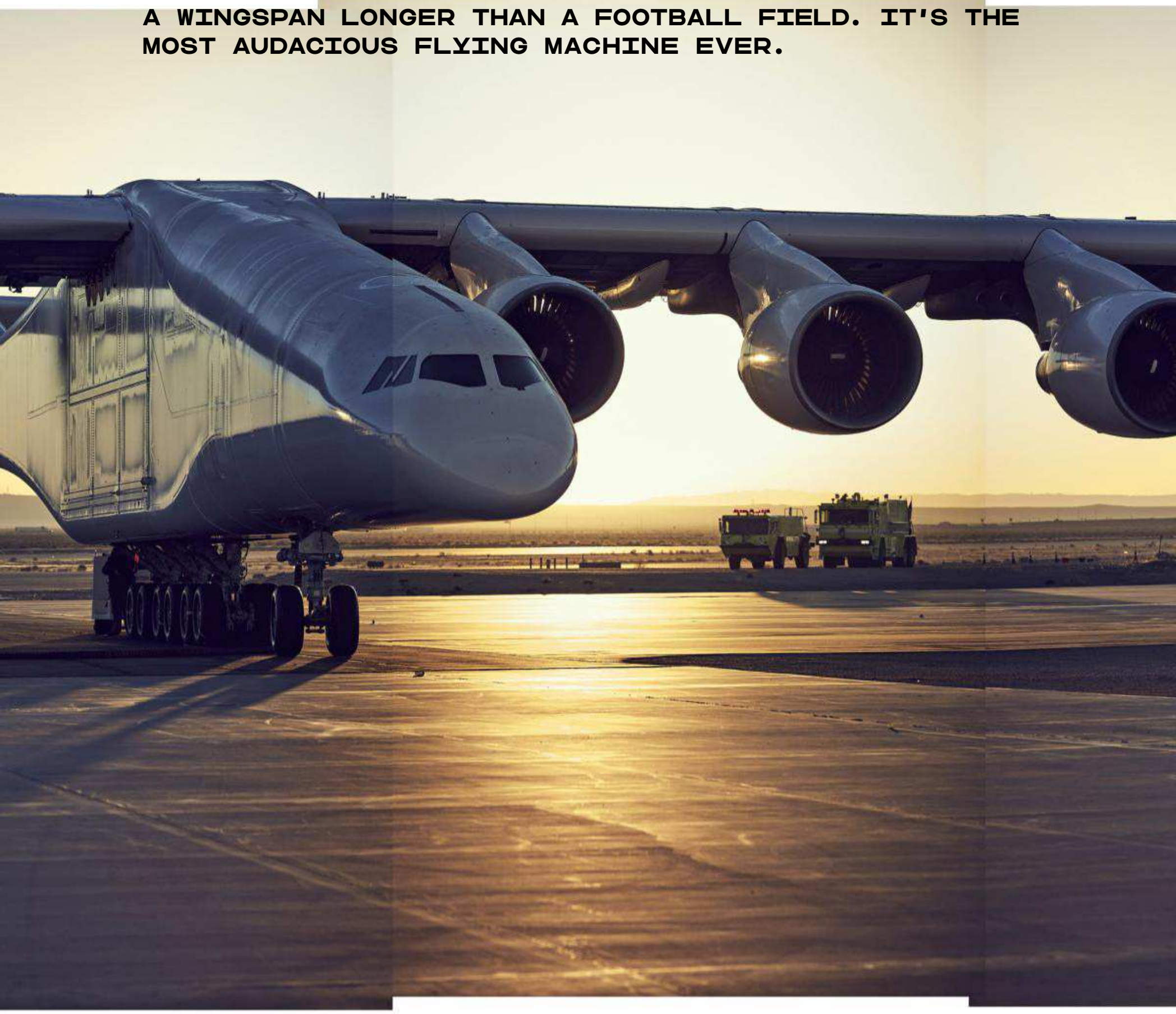
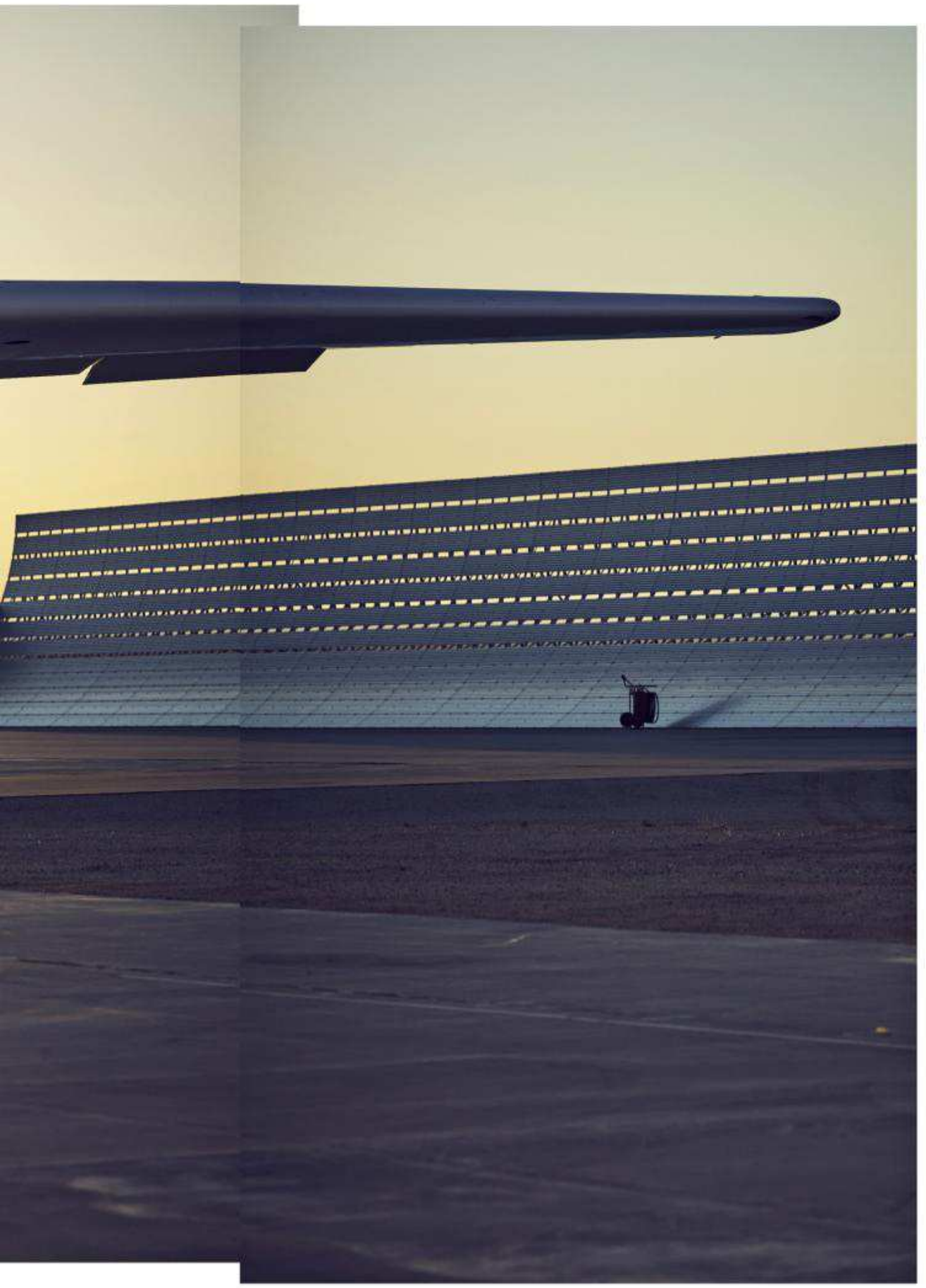
BY STEVEN LEVY

FEET OF CRAZY

PHOTOGRAPHS BY JOE PUGLIESE

ALT-AVIATION WIZARD BURT RUTAN SET OUT TO BUILD A PLANE THAT COULD HAUL ROCKETS TO THE EDGE OF SPACE. THEN HE PERSUADED MICROSOFT COFOUNDER PAUL ALLEN TO BUILD A DUAL-FUSELAGE BEAST WITH A WINGSPAN LONGER THAN A FOOTBALL FIELD. IT'S THE MOST AUDACIOUS FLYING MACHINE EVER.





ON

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Paul Allen, the reclusive billionaire and cofounder of Microsoft, stood in front of a group of reporters in Seattle and told them about his wild new plan.

Wearing the tech-Brahmin uniform of navy blazer, dress shirt, and conspicuously absent tie, Allen made some introductory remarks and then rolled a video simulation of a strange beast of an aircraft leaving an oversize hangar. This was *Stratolaunch*. It would be the largest airplane, by wingspan, ever created. The twin-fuselage, catamaran-style aircraft would be a flying launchpad, its purpose to heave a half-million-pound rocket ship to cruising altitude and then drop it, whereupon the rocket would ignite its engines for a fiery ascent into space. Allen's hope was that this extraordinary bird would be able to do quick laps between the ground and the stratosphere, making access to space no more exotic than a New York–to–Boston commuter flight.

Burt Rutan took the microphone next. Rutan, a gregarious designer of exotic aircraft, wore a light-blue work shirt and sported huge Elvis-style muttonchops. He was the original architect of the outlandish endeavor and the person who had sold Allen on the project. "Right here in front of us is a very large mistake," he said, landing heavily on the word *mistake* and jabbing his finger at a model of the plane. The problem, he explained, was that no one in the room could possibly grasp how friggin' big *Stratolaunch* would be. For them to have any sense, they'd have to understand that even a Boeing 747 would seem like a Tinkertoy in comparison. Rutan's devilish grin said it all: This would be a plane to defy the imagination. The plane, he and Allen said, would take its first flight in 2015.

Three years past that target date, the plane finally exists, and as Rutan promised, it is one big mama. As I discovered, nothing—not even a Rutan-approved scale model—can prepare you for an encounter with it.

This past December I traveled to the Mojave Air and Space Port, a desert city of giant industrial structures in Southern California, where *Stratolaunch* was built. The plane's facility on the eastern edge of the port stands out among the other structures. After walking through some drab offices, I was escorted into the approximately 100,000-square-foot hangar. The gleaming white *Stratolaunch* didn't just fill the expanse; it reached into every corner of it. There was no way to take in the monster with a single glance. Starting near its tail, I walked through and around it, craning my neck and stretching on my tiptoes to gather mental snapshots of the two fuselages and the white drag strip of a wing and stitch them together into one panoramic picture.

Everything about *Stratolaunch* is supersized. It has six screaming Pratt & Whitney turbofan jet engines, salvaged from three 747s. Its maximum takeoff weight is 1.3 million pounds. It's got more than 80 *miles* of wiring. Most astounding is its 385-foot wingspan, the spec that puts *Stratolaunch* in the history books. That number may not seem remarkable, but on a single airplane wing 385 feet is an eternity. It's a football field plus the end zones and a little bit more. If the Wright brothers had begun their initial Kitty Hawk flight at the tip of one *Stratolaunch* wing, they could have completed the journey and done it twice more before they reached the other end.

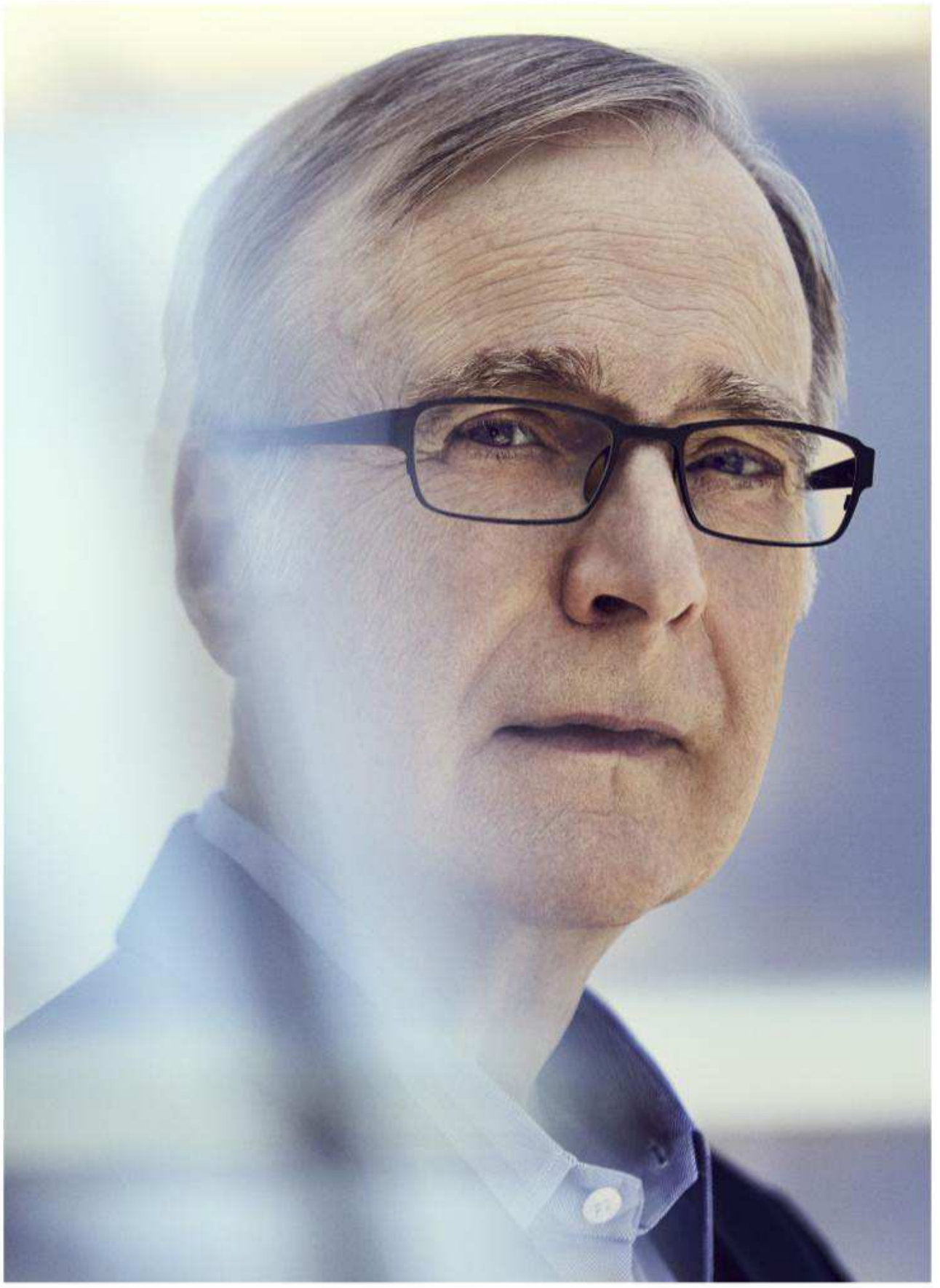
Though the two fuselages look identical, only the right one has a cockpit, largely preserved from one of the 747s, with a throttle, foot pedal, and even some analog displays that a commercial pilot working in the 1970s might find familiar. One of the seats is covered by a sheepskin-like cushion of the type often found in New York City taxis. Looking out the window, the second fuselage is so far away that it looks like a plane sitting on an adjacent runway.

It's hard to imagine this mammoth structure rising into the air. But the team—without Rutan, who retired in 2011—has been methodically taking it through a series of tests: bearing its own weight, firing its engines, taxiing down 2-plus miles of runway. Allen promises *Stratolaunch* will ascend as early as this fall.

Thousands of people will turn their eyes to Mojave when that first flight happens. But after that, what? The original plan was to create a more reliable and flexible way to shoot satellites into space. But while *Stratolaunch*'s development has dragged on, the private space industry has leaped ahead. Other billionaires, notably Elon Musk, have dazzled the world with fiery launches and wild achievements such as reusable rockets and orbiting sports cars. The industry is becoming increasingly competitive, and numerous companies are scheming to lower the cost and increase the reliability of rocket launches. Musk's SpaceX was going to supply Allen with the rockets *Stratolaunch* would carry, but it ditched the project years ago.

The mammoth aircraft inevitably brings to mind the *Spruce Goose*, the much-mocked giant airplane and pet project of tycoon Howard Hughes. Allen had visited the legendary plane in its home in an Oregon museum. That plane (it was actually made mostly of birch, not spruce) was intended to send supplies and soldiers to combat during World War II, but it flew only once, for just a mile, long after the conflict was over. *Stratolaunch*, too, could be obsolete before its massive wing ever reaches the sky. Is biggest better? Maybe. Maybe not.

But have you *seen* this thing?



Paul Allen, the billionaire funding Stratolaunch, has been fascinated with space travel since childhood. “When you see that giant plane, it’s a little nutty,” he says. But his goal is more practical: competing in the private space business.

As a teenager, Paul Allen was a sci-fi and rocketry nerd. He dreamed of becoming an astronaut, but that ambition was scuttled by nearsightedness. His childhood bedroom was filled with science fiction and space books. Bill Gates remembers Allen’s obsession. “Even when I first met him—he was in tenth grade and I was in eighth—he had read way more science fiction than anyone else,” says Gates, who later founded Microsoft with Allen. “Way more.” One of Allen’s favorites was a popular science classic called *Rockets, Missiles, and Space Travel*, by Willy Ley, first published in 1944. As Allen tells it in his memoir, he was crushed when he visited his parents as an adult and went to his old room to reference a book. He discovered that his mother had sold his collection. (The sale price: $75.) Using a blowup of an old photo of the room, Allen dispatched scouts to painstakingly re-create his boyhood library.

Allen never stopped thinking about space. In April 1981, during crunch time for Microsoft’s most important project—developing an operating system for the upcoming IBM personal computer—Allen up and left, joining a colleague on a field trip to Florida to see the first space shuttle launch. (Gates, for the record, still seems a bit annoyed about that.) “It was unbelievably impressive,” Allen says now of that launch. But he never seriously imagined getting involved in rocketry, until he met Burt Rutan.

Rutan had been hooked on airplanes since he was 8 years old. He started gaining recognition in the 1970s, selling plans for small aircraft that intrepid enthusiasts could build for themselves. His designs reimagined what a plane could be, changing up the placement of fins, wings, and even cockpits. In 1982 he started his company, Scaled Composites, in the California desert. He built planes that looked like praying mantises and others that had the whimsy of a Playmobil toy. (Five of his creations are now on display in the Smithsonian National Air and Space Museum.) The company changed ownership several times over the years, until Northrop Grumman acquired it a decade ago.

As Scaled Composites churned out cunning, award-winning designs, it became the aviation equivalent of Willy Wonka's chocolate factory, staffed by stubborn outcasts who had been lured by the charisma of their iconoclast boss. "It was the dream job," says Matt Stinemetze, Scaled's chief engineer, who joined in his early twenties. "Burt was this legendary designer who designed all these home-builds that were weird and backward. It was almost like we always made these very different things because we could."

By 1996, Allen, who had long since left Microsoft and was pursuing an eclectic range of investments (including snapping up the Portland Trail Blazers), had begun exploring the idea of delivering broadband from the sky. He heard about a Rutan creation he thought might be useful for this enterprise, and he flew to Mojave in his personal Boeing 757 to ask about it face-to-face. Nothing came of the conversation that day—except that Rutan learned Allen was a "space nut" with money to spend.

It was a fateful connection. A few years later, when Rutan was contemplating building the first private rocket that could send a human into space, he made a pilgrimage to Seattle to visit Allen. One aspect of his plan, he said, was to launch a manned spaceship from an airplane, not a launch pad. Rutan thought he could do it with less than $20 million.

Allen saw in Rutan's idea an opportunity to open up space the same way he and Bill Gates had popularized computers. He agreed to fund the spaceship, and they closed the deal with a handshake. They also decided to enter the competition for the Ansari XPrize, which offered $10 million to the first team to send a person into suborbital space twice in two weeks using the same equipment.

Rutan called that effort *SpaceShipOne*. Richard Branson, another billionaire fascinated by space, and who knew Rutan, caught wind of it and raced to the Mojave. He chipped in $1 million in exchange for branding the rocket ship with the Virgin logo. Branson's ultimate interest was space tourism—high-priced, suborbital thrill rides—and he felt that *SpaceShipOne* could give him a high-profile start.

On September 29, 2004, a *SpaceShipOne* test pilot barely, but triumphantly, crossed the 62-mile border between Earth's atmosphere and space. Five days later, another pilot repeated the trick. Rutan and Allen won the XPrize.

Allen's excitement at the achievement was dampened by his increasing anxiety. The first few *SpaceShipOne* sorties were tense affairs, with unplanned spins and even a near-crash landing. The space shuttle *Columbia*'s fatal 2003 reentry into Earth's atmosphere, which killed seven astronauts, was still fresh, and he was haunted by the prospect that they might lose one of the pilots. As Allen later wrote, when the rockets fired during the prize-winning *SpaceShipOne* flight, Branson asked him, "Isn't this better than the best sex you've ever had?" Allen thought otherwise. "If I was this anxious during any kind of interpersonal activity, I couldn't enjoy it very much," he told himself. Branson wanted to license the *SpaceShipOne* technology from Allen for space tourism, and Allen agreed. Branson's effort to develop Virgin Galactic ended up marred by two fatal accidents, the exact scenario that had frightened Allen. (Virgin Galactic is still planning to send customers for a 90-minute whirl.) Allen was out of the space race.

He turned his focus to his new institute on the human brain, a real estate push in his native Seattle, and a different kind of ship: his roughly 414-foot yacht, known as the *Octopus*.

Rutan, meanwhile, was thinking about the Brobdingnagian airplane that would eventually become *Stratolaunch*. In 1992 he had been summoned by Antonio Elias, a senior executive at a commercial space company called Orbital Sciences Corporation, to meet with a small group. Elias was exploring the idea of building a heavy spacecraft that could be launched from a giant airplane.

One problem with ground-based rockets is that they can take off from only a small number of facilities, like the Kennedy Space Center or Vandenberg Air Force Base, where competition for launch time creates long delays. A plane-based launch would create new possibilities.

But a plane that big had other challenges. Rutan's analysis concluded that to deliver the weight of the rocket Elias was talking about—up to 640,000 pounds—you'd need a wingspan of almost 400 feet. That wing had to be strong too. In addition to two fuselages and tons of fuel, it would be carrying a set of jet engines and that massive vehicle. Rutan planned to build the plane from nonmetal composites, rather than aluminum, to keep the weight down, but making the composite strong enough presented another problem. Rutan solved this dilemma in part with a process called pultrusion, in which a machine pulls a material at a constant rate and then bakes it until it hardens, a way to mold huge segments of the plane with a consistent strength. This technique let the engineers manufacture the very long spars that fortify the giant wing.

Rutan began working on a design, even as he realized that the odds were against it ever being built. Using traditional construction methods and materials, the price tag might stretch past a billion, perhaps even reaching the cost of a nuclear aircraft carrier. He figured he could build it more cheaply, especially if he took his scavenger mentality to the limit. "I reasoned that if I could lift out engines, pylons, landing gear, actuators, electricals, and cockpit stuff from 747s, it was doable for us," he says.

Over the next 20 years, Rutan worked with three prospective customers as he continued designing what he referred to as the Big Airplane. He won't say who the customers were, but none of them took the step of commissioning it.

Then Allen decided to get back in the space business.

When I first talked to Allen, he was vague about why he decided to fund Stratolaunch. "I did my thing, we won the prize," he says, speaking by video conference from Santa Fe, New Mexico, in the former home of Georgia O'Keeffe. It's one of at least seven properties he owns. He's seated with his legs stretched out on a deep couch, almost swallowed up by giant patterned seat cushions. I'm talking to him from Seattle, and I'm not sure if his lack of eye contact with me is a result of shyness or because my screen image isn't aligned with the camera. "Burt Rutan planted a seed that he wanted to do something orbital with a scaled-up plane," he finally says.

Allen later said he had another reason: He'd been watching as NASA pulled back on space operations and private businesses emerged to fill the gaps. The terrain was becoming irresistible, and he figured this was his opportunity.

Let Richard Branson offer suborbital thrill rides to civilians. Let Elon Musk go to Mars. Allen suspected there was another business proposition. The cost of building satellites was dropping as computers, cameras, and sensors became cheaper and more powerful. Their uses were growing too. They could be used to detect illegal ocean fishing—another Allen-funded project—or monitor humanitarian crises. If there were a reliable and thrifty way to launch satellites, people might come up with more uses, creating an even bigger market. That's what happened with PCs.

Allen thought air launches could hasten that process. They are not as sensitive to weather as those held at traditional vertical launch facilities, allowing for more flexible takeoffs. They could also be more affordable, as the airplane can be

reused many times. But no one had ever built an air-launch system capable of heaving super-heavy payloads into orbit.

Allen incorporated the Stratolaunch company and set about building the huge hangar for the plane in Mojave, next to Scaled Composites. (The plane's original codename was Maliboo, but the Scaled Composites people called it Roc, after the giant bird of prey in Middle Eastern mythology. Rutan jokes that it's really an acronym for Rutan's on Crack.)

Allen was still queasy about putting lives in peril, but this time he had a rationale. "There's a distinction between taking someone's ticket for a joyride in space and having a commercial test pilot who knows the risk," Allen says. Even so, he admits that it takes fortitude to send any human into the great void. "It's different than having a bug in Microsoft Word or something," he adds. "You have to be comfortable that something bad might happen—it's a whole other level of anxiety."

Though retired, Rutan still sits on the Stratolaunch board. He makes a point to credit the designers at Scaled Composites, albeit in his own fashion: "Burt Rutan designed different configurations for the Big Airplane for over 20 years," he says, referring to himself in the third person. "But Burt is not the designer of the airplane in Mojave now."

That's kind of a shame because, as Rutan describes it, his original vision for *Stratolaunch* was even more radical than the plane now in a hangar in the Mojave spaceport. He had situated the cockpit toward the tail, attached to a massive foil connecting the dual fuselages. The pilot's placement at the back of the aircraft would offer a view of the rest of the vehicle, making it easier to control. Stratolaunch's current CEO, Jean Floyd, explains that the designers determined that the rear cockpit and its foil put too much weight at the back of the plane, so they switched early on to a design where the two fuselages would be connected only by the main wing.

The team worked to speed up construction by using off-the-shelf parts whenever possible, the most conspicuous example being the repurposing of three 747s. But the surface of the plane had to be created from scratch. "This vehicle has some of the largest composite components ever built in the world, made by hand by fabricators, all made by our guys," says Jacob Leichtweisz-Fortier, who works on the plane. The most massive pieces were 285-foot spars that give the wing its resiliency, each one weighing 18,000 pounds. The team first constructed the wing out of the gargantuan spars and built the rest of the plane around it.

The plane's extreme size led to some unexpected complications: The scaffolding needed to assemble the wing had to be about 40 feet high. "It starts to look like a building," Stinemetze says. "In fact, the way California treats it, it is a building. It has to meet codes for sprinklers and electrical power." When the plane was ready to emerge from its scaffolding and get towed out of the hangar, just lowering it 2 feet to the ground took eight hours, Floyd says.

While the plane was taking shape, Stratolaunch was struggling to find rockets to launch. For a few years, Allen's company searched for a replacement for SpaceX and finally settled on the Pegasus XL rocket, built by Orbital ATK. (Orbital is also owned by Northrop Grumman.) But the choice of rocket was anticlimactic. More than 40 Pegasus rockets have already launched from the air, usually from a converted Lockheed L011 Tristar, a commercial airliner that is almost completely retired. It calls into question the whole Stratolaunch enterprise. Why build the world's biggest aircraft just to launch a rocket with a small payload that can be shot off from a creaky out-of-service plane?

For Stratolaunch to fulfill its promise, Allen realized, he would have to build his own rockets. In 2016, Stratolaunch began that process. "At first we looked at using off-the-shelf engines, even rebuilding surplus space shuttle engines," Allen says. But then the company's engineers realized that new technologies, especially 3-D printing, would be more efficient. "You can just print these engines almost from scratch for so much less," Allen says, estimating that a new engine can be printed for about a fifth of the cost of repurposing space shuttle overstock. Stratolaunch formed a team of rocket designers, led by SpaceX's former head of propulsion, Jeff Thornburg. The company will test its engines at a NASA facility in Stennis, Mississippi.

Sharing their road map publicly for the first time, Thornburg and Floyd laid out their plans for Stratolaunch: Its first custom rocket ship will be considerably bigger than the Pegasus, able to transport multiple satellites or other payloads. This medium-size rocket is nicknamed Kraken, after the legendary Icelandic sea monster. Floyd says customers will be able to use it to get satellites into low Earth orbit for less than $30 million, a competitive price and about half of what SpaceX charges for a launch of its Falcon 9 rocket. Floyd estimates that Kraken will be operational in 2022.

Burt Rutan, a designer of exotic aircraft, spent two decades developing what he called the Big Airplane. He retired in 2011, and *Stratolaunch* does not include some of his more out-there ideas. "Burt is not the designer of the airplane in Mojave now," he says.

The next steps are more ambitious. In a project codenamed Black Ice, Stratolaunch is designing reusable space planes that will take off from the big airplane and go into orbit. The first one will be programmed to open its bay doors once in orbit and release its payload, perhaps even a fleet of satellites, into space. And then it will return to Earth. The idea is not all that different from the original space shuttle, which was a reusable vehicle that could also steer itself down from orbit to land on a runway. It can "come back and land at Mojave where the plane is waiting, the fuel system is waiting," Floyd says. "You roll up underneath the plane, you refuel, you put the next payload in, and you go again." Finally, Stratolaunch aims to build a second version of Black Ice that can carry astronauts. That ship won't be flying for at least a decade.

But by then, who knows what Stratolaunch's competitors will be up to? Though Allen reportedly plans to spend hundreds of millions of dollars on his space enterprise, and is its sole investor, billions are being plowed into companies such as Musk's SpaceX and Jeff Bezos' Blue Origin, both of which are trying to cut costs in the private space industry with reusable booster rockets that take off from the ground, not air launches. The companies have deals with NASA and commercial customers worth billions of dollars. Traditional defense contractors are also developing their own orbital rockets. And a new generation of people are thinking up new approaches to space. Earlier this year came news that a startup called SpinLaunch was developing a system in which a catapult-like contraption could efficiently zip satellites into orbit, aiming to cut prices to less than $500,000 per launch. Investors include Airbus Ventures and Kleiner Perkins.

Stratolaunch is not commenting on whether it has any customers signed up. Floyd suggests the business part of Stratolaunch is a work in progress. "They love this," he says, "but this has to fly first." In other words, get the thing in the air, then they'll talk.

Flying the thing might be less of an issue than landing it. That's what Chris Guarente, chief test pilot for Scaled Composites, tells me as I take *Stratolaunch* to the skies. Virtually, at least. We are sitting in the cockpit of the *Stratolaunch* simulator, a few hundred feet away from the real thing in its giant hangar. I'm wearing a gray flight suit and a helmet. Guarente, known to everyone as Duff (a test pilot thing, I guess), is instructing me on how to use the standard 747 controls—throttle, pedals, yoke—to taxi down the long Mojave runway.

Even before we take off, I can see why Rutan thought of putting the cockpit in a tail section. It's tricky to compensate for the fact that, while we are on the far right of the runway, seemingly only inches from the sands, the left fuselage is 100 feet away; yes, it's coming with us. Finally, after our speed mounts on a very long taxi, I pull back the yoke and we slowly ascend. Ahead of us is a mountain range, maybe 5,000 feet high. My altimeter—one of those analog dials with a needle pointing to the number—keeps rising, and I'm up to 11,000 feet when we clear it. Duff instructs me to make some turns and see how the plane responds.

"Every objective you have during that flight is based on 'What do I need to do to know I can land this airplane,' " says Duff, who flew F-16s in the military. On *Stratolaunch*'s maiden voyage, the pilots won't even retract the landing gear. "It's just one more thing that could go wrong," Duff tells me. He repeats once more, as if I'd missed it, "The mission is to familiarize the pilot and make sure the airplane is capable of landing."

I mention that it's a bit alarming to hear him talk about the plane's ability to land in the conditional. "We do believe it is capable of landing," Duff says. "But this is the first time you find out if it really is."

One tricky part of the landing, Scaled's Stinemetze says, might be handling a touchdown from one side of an awkward two-fuselage configuration. "You can touch that other boom down before you're on the ground, so there's all these weird things that can happen," he says.

The first flight is supposed to happen soon. Maybe September. Maybe a bit later. Next year they will see how the plane flies with a Pegasus attached. Once the plane takes off with a rocket in tow, the Scaled Composites contract could end, at which point Allen's company would be the sole entity in charge of the aircraft. *Stratolaunch* will remain based at its Mojave hangar while its engineers prepare it for more tests. As early as 2020, the *Stratolaunch* crew will release the rocket from its hitch 35,000 feet over the Pacific Ocean. The rocket will ignite its boosters and begin a two-minute ascent into space.

For some members of the team that's been building *Stratolaunch* for seven years, though, the rockets are an abstraction. "We just want to see this gigantic airplane fly," says Niki Dugue, one of Scaled Composites' engineers.

Allen isn't one to show exuberance, and when he speaks about the plane he focuses on its future utility. "When you see that giant plane, it's a little nutty," he says. "And you don't build it unless you're very serious, not only about wanting to see the plane fly but to see it fulfill its purpose. Which is getting vehicles in orbit."

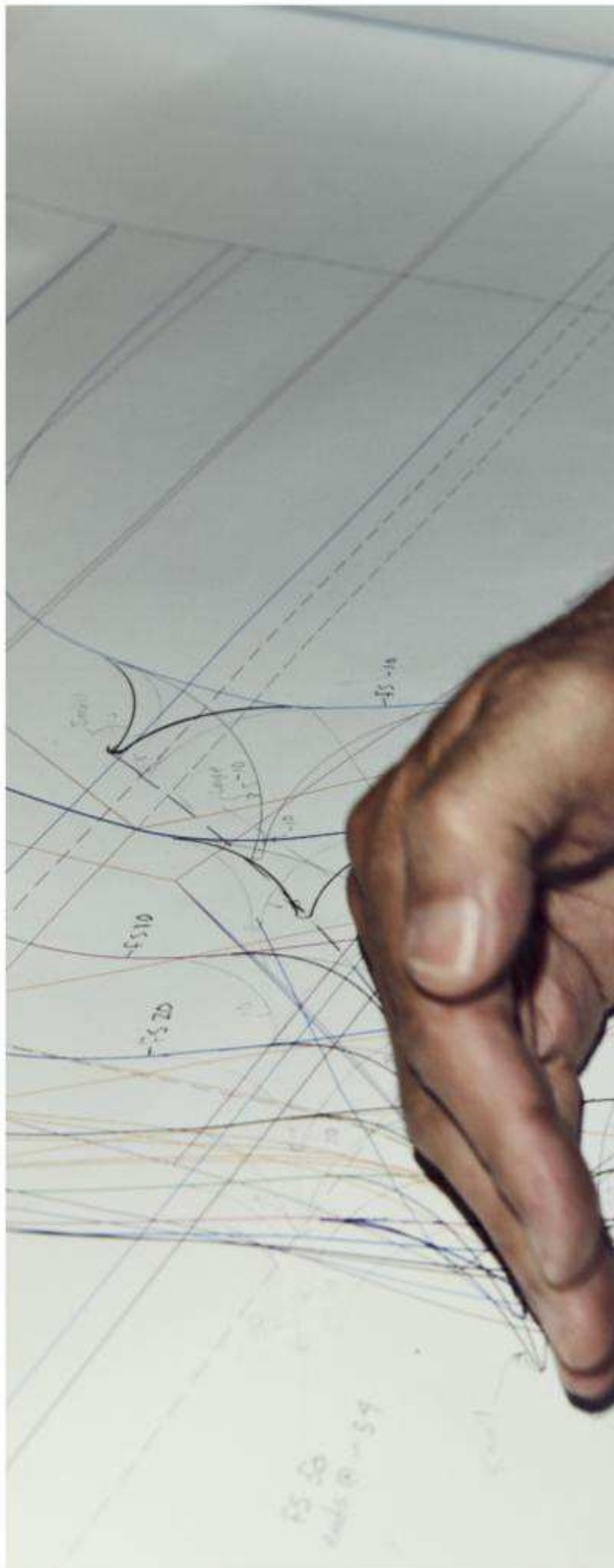
Yet it's pretty easy to fathom that building the world's biggest plane is, for Allen, as much about an adventure worthy of the sci-fi books he painstakingly recovered after his mother sold them off.

It certainly was for Burt Rutan. "This airplane should be called the *Savior*," he says. We are in his sprawling lakefront home in Coeur d'Alene, Idaho. Rutan calls it the "cabin." The walls of his in-home museum are festooned with awards, mementos, and models of his creations. His trademark muttonchop sideburns are gray, but his wide blue eyes are still as vivid as high-altitude sky.

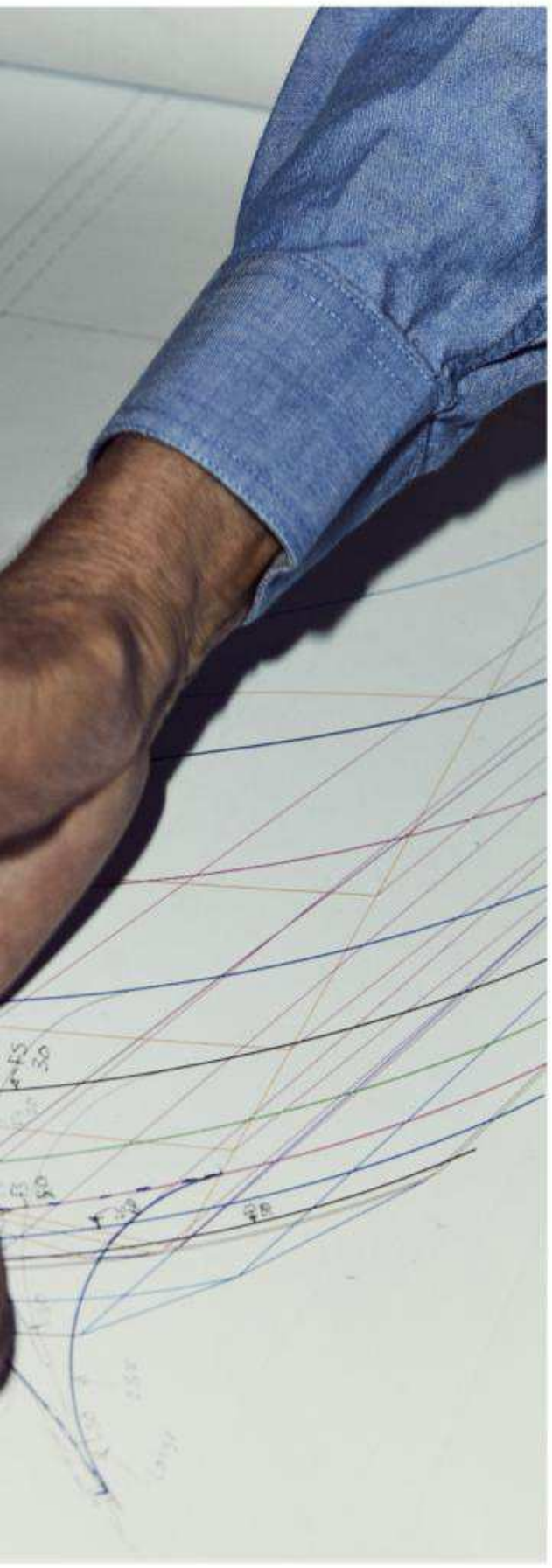
To explain why he refers to *Stratolaunch* that way, the septuagenarian springs out of his chair and looks toward the ceiling with his jaw theatrically dropped, as if the double-barreled white beast has suddenly appeared in his living room.

"Almost everybody who sees it for the first time says, '*Jeeeee-zus Christ!*' " he says, lifting his arms and shaking his hands in hosannas. "And that's why you call it the *Savior*."

It's like the rockets hardly matter. Let the bird fly.



STEVEN LEVY *(@StevenLevy) wrote about Palmer Luckey's virtual border wall in issue 26.07.*



Rutan explains his design for an amphibious plane (left). He keeps models of many of his aircraft, including the *Boomerang*, pictured above with Rutan's role model: Elvis Presley. ("Music died when Elvis died," he says.)

HOMES DESTROYED. BODIES WRECKED. FAMILIES RIPPED APART. THE BASHAR AL-ASSAD REGIME'S INDISCRIMINATE AIR STRIKES HAVE TERRORIZED SYRIAN CIVILIANS FOR YEARS. NOW A SMALL BAND OF ACTIVIST-ENTREPRENEURS IS BUILDING A SENSOR NETWORK THAT LISTENS FOR WARPLANES AND WARNS PEOPLE WHEN AND WHERE THE BOMBS WILL FALL—GIVING THEM JUST ENOUGH TIME TO SURVIVE.

by

DANNY GOLD

EVERY SECOND COUNTS

ON THE MORNING OF APRIL 11,

Abu al-Nour was lounging at home in a small town in Syria's Idlib Province. It was a pleasant day, and his seven children—ages 2 to 23—were playing outside or studying inside. The house was small, but al-Nour was proud of it. He had built it himself and enjoyed having family and friends over to spend time in the big yard. His wife was cooking lunch in the kitchen.

Al-Nour is a farmer, as were many of the town's residents, but since the Syrian civil war started in 2011, fuel and fertilizer prices had shot up well beyond his means. Al-Nour had been getting by with the odd construction job or harvest work here and there. The area had fallen to rebel forces in 2012, and though his village was too tiny for the rebels to bother with much, he'd noticed fighters from the Free Idlib Army and Jaysh al-Izza groups passing through on occasion.

Being in rebel-held territory meant government air strikes. The bombings began in 2012 and got worse in 2014. Many villagers fled out of fear. Others fell deeper into poverty, their businesses ruined by the relentless conflict. When the first air strike hit al-Nour's neighborhood, he says, it killed eight people from one family. Al-Nour tried to help with rescue efforts, but instead was overcome with grief, unable to move. Afterward, he couldn't stop imagining what could happen to his family. Finally, five long years into this reality, he heard about a service called Sentry from a friend. If he signed up, it would send him a Facebook or Telegram message to let him know a government warplane was heading his way.

Around noon on that day in April, al-Nour's phone lit up with an urgent warning: A Syrian jet had just taken off from Hama air base 50 miles away. It was flying toward his village.

He panicked.

He shouted to his family and grabbed the younger children. The group dashed out to a makeshift bomb shelter that al-Nour called his "cave." Many residents of the heavily bombed areas in Idlib had dug similar shelters—really, just holes in the ground—and fitted them with something like storm-cellar doors.

Al-Nour managed to get all his children into the cave, but not his wife. He kept calling her name as he heard the awful sound of an approaching jet overhead. His wife reached the door to the shelter just as a bomb hit. Al-Nour remembers the door blowing off the cave, everything shaking, and an almost unbearable pressure in his ears. "It smelled of dust and fire," he says. "The dust was everywhere."

Shrapnel had pierced his wife's back. Some of his children were in shock; others were crying. Through the smoke, he could tell that his house was destroyed. Still, everyone was alive. For that he was grateful. "We saw the death with our own eyes," al-Nour says over the phone through an interpreter. "Without the Sentry warning, my family and I would probably be dead." (Al-Nour is a pseudonym; he fears using his real name.)

In the seven years since the start of Syria's civil war, it's estimated that at least 500,000 Syrians have been killed. That number includes tens of thousands of civilians killed in air strikes carried out by Syrian president Bashar al-Assad's regime and its allies. (Meanwhile, US and coalition forces are estimated to have killed as many as 6,200 Syrian civilians in their air campaign against ISIS.) Assad's forces have been accused by the international community of war crimes for indiscriminate bombings. Six million Syrians have fled the country, creating a refugee crisis in the region and the world. International efforts to find a peaceful resolution continue to fail. The Assad regime has slowly regained territory; about two-thirds of the people in Syria currently live in areas under government control. The rest are in places held by an array of rebel groups as well as Kurdish and Turkish forces. Millions of people still live in unending fear of the sound of fighter jets overhead.

The conflict has left many Syrians feeling defeated. Huge swaths of the country have been laid to waste, and the humanitarian crisis isn't expected to get better with coming government offenses. And yet even if these larger forces are implacable, a small effort can sometimes make a meaningful difference—like helping a family of nine escape with their lives.

The warning that came over al-Nour's phone was created by three men—two Americans, one a hacker turned government technologist, the other an entrepreneur, and a Syrian coder. The three knew they couldn't stop the bombings. But they felt sure they could use technology to give people like al-Nour a better chance of survival. They're now building what you might call a Shazam for air strikes, using sound to predict when and where the bombs will rain down next. And thus opening a crucial window of time between life and death.

As a kid in rural McHenry County, Illinois, John Jaeger didn't have much to do until his stepdad built him a homebrew 486 computer. It was the late '80s—still the early days of PCs—and he mostly played videogames. Eventually he found his way onto a BBS with connections to the demoscene, an early underground subculture obsessed with electronic music and computer graphics. By the time he was 15, Jaeger was in deep with hackers, software crackers, and phone phreakers.

"We would exploit weaknesses in computer networks in order to gain administrative privileges and learn how the networks worked," Jaeger says. He messed around but adds that he didn't do anything more "destructive" than hack into Harvard's system to give himself a Harvard.edu email address.

Jaeger took a job at modem manufacturer US Robotics right out of high school, followed by a gig at General Electric Medical Systems. The promise of "good drugs and startup parties" lured him to Silicon Valley in the late '90s. The adventure, he says, was "forgettable." He took computer security and network management jobs before working his way up to IT director. "I basically made all the wrong decisions," he says. "Instead of becoming a multibillionaire, I went and worked for three companies that don't exist anymore."

Jaeger moved to Chicago and got a job in the financial industry. He designed and developed a trading platform and did risk management analysis. He was enjoying the work, but then the financial crisis hit. "I saw 20- and 30-year veterans of Wall Street soiling their trousers, genuinely scared," he says. "It was really humbling." That experience, he says, turned him off finance. But it was another three years before he finally left the industry.

Through a friend who had worked on President Barack Obama's reelection campaign, he got an introduction to someone in the State Department. It was 2012, a year after the start of the Arab Spring, and the US government

was recruiting people who could bring corporate experience and technical expertise to Syria. Jaeger wasn't exactly familiar with the civil war that was building. "I had no idea what was going on," he says. But he wanted to go overseas, so he relocated to Istanbul and basically became a consultant for the people trying to achieve a semblance of normalcy in areas of Syria that weren't under Assad's control.

"You had a whole lot of chiropractors and dentists suddenly respond to the needs of their local communities in a way they had never anticipated," Jaeger says. "These guys need clean water. These guys need power. These folks need medicine." Jaeger's job was to help them figure out how to provide services and maintain some stable governance.

In October 2012, he started working with journalists and developing a program to support Syrian independent media. But two years in, the conflict started wearing on him. Jaeger had grown attached to many of his Syrian contacts and mourned when they were killed. Everyone he knew had lost family. It became clear that the biggest problem he could address was the bombing of civilians.

Options for mitigating the damage from air strikes, Jaeger knew, were few. And most were out of his reach. You could stop them. But even the international community had failed to do that. You could treat people after the air strikes hit. Various groups, like Syria Civil Defense, were doing that work. Or you could warn people ahead of time.

That last option seemed within his technical expertise. So he approached the State Department. But when he couldn't rally any interest in the idea of an early-warning alert system, he left the agency in May 2015. He was convinced he was onto something. But he needed help.

Dave Levin is a Wharton MBA who had worked for the UN Global Compact under Kofi Annan, had been an entrepreneur in the Philippines, and had consulted for McKinsey. In 2014, Levin founded Refugee Open Ware, an organization that helps people start projects using tech to do good in troubled regions. He was working in Jordan on an effort to develop 3-D-printed prosthetics for victims of war when a Syrian activist connected him to Jaeger. Levin flew to Turkey and the two met to talk about Jaeger's idea. Levin signed on right away. (Refugee Open Ware has since invested in the project, and Levin splits his time between the organizations.)

In November 2015, two months after he met Levin, Jaeger got another lead. An expat friend in Turkey told him there was someone he needed to meet, a Syrian coder who was looking for ways to warn civilians about air strikes. The man, who goes by the alias Murad for safety reasons, grew up in a prominent, largely apolitical family in Damascus.

At university, Murad met people from other parts of Syria, young men and women who hadn't grown up as sheltered as he had. Their stories of poverty and repression, of relatives imprisoned or killed by the government, shook Murad. He started to understand the grim authoritarian reality of his country.

When the war started, Murad was in his mid-twenties and a recent graduate with a degree in management information systems. He started working with groups that were housing displaced people. Eventually

OBSERVERS WERE ALREADY WATCHING FOR PLANES. IF HALA COULD CAPTURE THAT DATA AND CONNECT IT TO WHERE THOSE PLANES DROPPED BOMBS, IT WOULD HAVE THE FOUNDATION OF A PREDICTION SYSTEM.

JOHN JAEGER

PHOTOGRAPHS BY RENA EFFENDI

DANNY GOLD *(@DGisSERIOUS) is a writer and filmmaker based in Brooklyn.*

he realized that this activity had made him a target of the regime, and he fled to Jordan. There, he volunteered as a teacher in a refugee camp. But six months later, troubled by stories he heard from Syrians who were fleeing their homes, he felt he had to return.

Once he got back to Syria, Murad began teaching activists how to keep the government from intercepting digital communications. But regime thugs threatened his family, and he had to flee again. This time he went to Turkey. He started organizing schools for the growing community of Syrian refugees there and helping Syria Civil Defense with data management. As the air war ramped up, he saw more and more Syrians arriving mutilated—and traumatized. "This was horrible," he says. "People without arms or legs."

Murad had an idea: Start connecting civil defense organizations in different towns so they could better communicate about impending attacks. He mentioned the idea to Jaeger's friend. Jaeger and Murad soon met for coffee, and Jaeger offered him a job. It came with low pay, long hours, and no job security. Murad was all in.

With a team in place, the group was ready for the most arduous startup task: fundraising. Jaeger went to VCs, who told him the idea was great—but would never generate billions. They pointed him toward social-impact investors, who told him the idea was great—but they didn't invest in the "conflict space." They suggested foundations—which said they didn't invest in for-profit businesses and sent him to VCs.

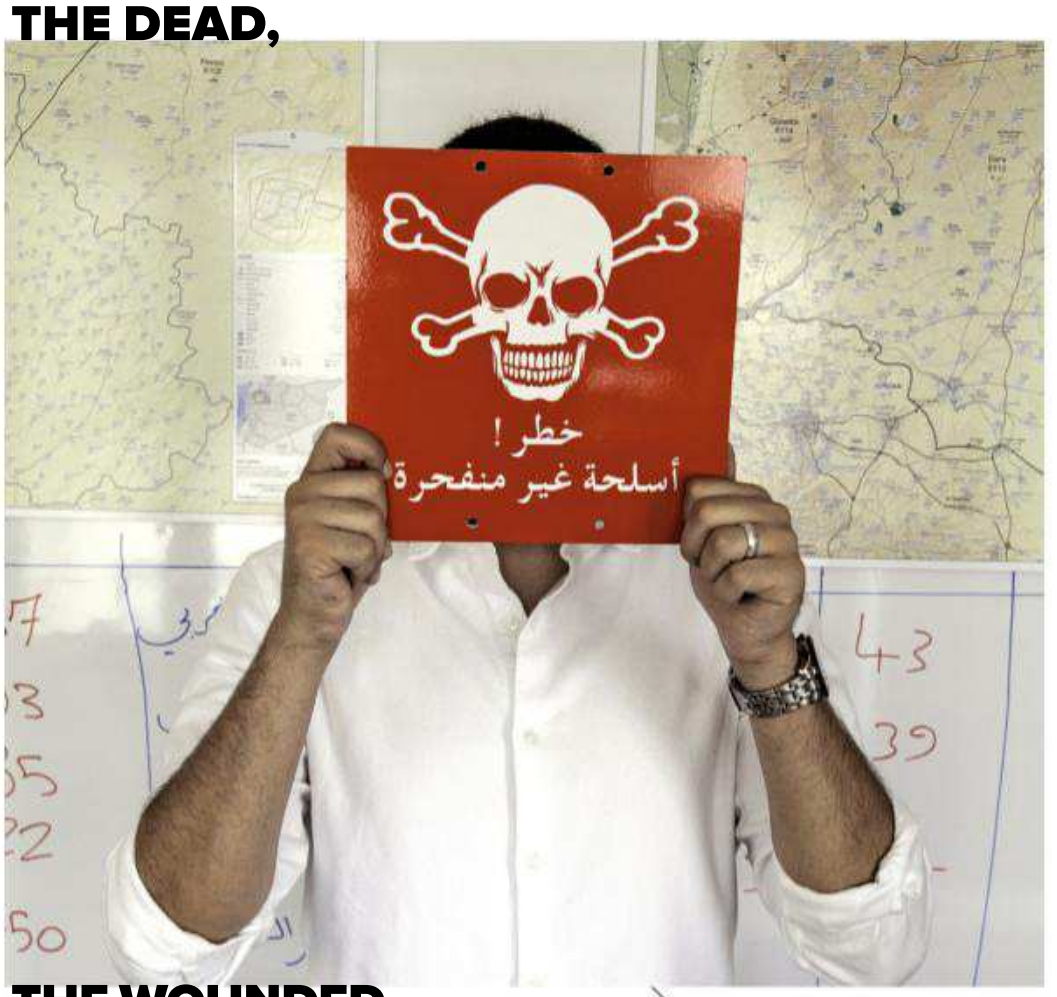
Screw it, thought Jaeger. In late 2015, the cofounders put together what they could from their personal bank accounts and managed to get some funding from an angel investor Levin knew. It was time for their startup, which Jaeger had named Hala Systems, to try to make a business out of saving lives.

During World War II, British farmers and pub owners in rural areas along the flight paths of German warplanes would phone ahead to big cities, warning them when the Luftwaffe was on the way. Seventy years later, Syrian civilians set up a similar ad hoc system. People who lived near military bases kept watch; when they saw a warplane take off, they used walkie-talkies to notify other people, who would contact others, spreading the word up the chain. Many of the participants were members of Syria Civil Defense, known as the White Helmets, who also served as rescue workers. But the process was spotty, unreliable. There was no systematic way for observations to come in and warnings to go out.

Jaeger thought that with the right technology it should be possible to design a better system. People were already watching for planes. If Hala could capture that information and connect it with reports of where those planes dropped their bombs, it would have the foundation of a prediction system. That data could be plugged into a formula that could calculate where the warplanes were most likely headed, taking into account the type of plane, trajectory, previous flight patterns, and other factors.

The Hala team started reaching out to the people who were monitoring the planes, including the White Helmets. At the same time, the team hacked together the first iteration of a system that would analyze data

DAY AFTER DAY, FROM HALA'S OFFICE, MURAD MONITORED THE AFTERMATH OF THE AIR STRIKES—THE DEAD, THE WOUNDED AND THE DYING, THE BODIES, THE BLOOD, AND THE MAIMED LIMBS. "YOU CANNOT STOP CRYING. AND YOU CAN'T GET USED TO IT."



MURAD

ABOVE, MURAD HOLDS A SYRIA CIVIL DEFENSE WARNING SIGN THAT READS "DANGER! UNEXPLODED ORDNANCE."

from the aircraft monitors, predict where the planes were headed, and broadcast alerts to people under threat of attack. Jaeger and Murad sketched it out, eventually filling up a notebook and using napkins to get the rest down. Jaeger says at first the system was just a bunch of if/then statements, a logic tree, and an Android app.

Basically, if someone saw, for example, a Russian-built MIG-23 Syrian warplane take off from Hama air base, then entered that information into the system—now called Sentry—it would issue a warning via social media with predictions about when an attack could be expected to hit a targeted area. It might estimate that the jet could be headed for the town of, say, Darkush with an ETA of 14 minutes, or Jisr al-Shughur in 13. When more people reported a specific plane as it flew over different locations, Sentry could then send more specific and accurate warnings directly to people in threatened areas.

As the team gathered data, they constantly tweaked the formula. Everything was trial and error. "One of the things we learned early on was that our model for predicting arrival times was super aggressive," Jaeger says of Sentry before it was released to the public. "It had planes arriving much faster than they actually did." They couldn't figure out what was wrong. Then they talked to a pilot who had defected from the Syrian air force. "Oh, that's not how we fly that plane," the pilot told Jaeger when the team showed him the system. The program assumed jets would always fly at maximum cruising speed, but the actual speeds were much lower, most likely to conserve fuel. "When we fly that plane, we fly it at exactly these altitudes and speeds at these intervals, using these waypoints," the pilot said. With that information, the Hala team was able to fine-tune Sentry's predictions to be accurate to within 30 seconds of the warplane's arrival.

DAVE LEVIN

HOW THE SENTRY SYSTEM WORKS

Hala's warning system relies on both human observers and remote sensors to collect data on potential air strikes. The startup is working toward making its network more autonomous, the better to save lives. —Andrea Powell

1__When observers near government air bases spot warplanes taking off, they enter the type of aircraft, heading, and coordinates into an Android app, which sends the info to Hala's servers.

2__Sensor modules placed in trees or atop buildings collect acoustic data, which helps Sentry confirm the type of plane, its location, and flight path.

3__Software crunches all the data and compares it to past attacks, predicting the likelihood of an air raid, as well as when and where it might occur.

4__If the potential for an air strike is high enough, the system generates an alert that's broadcast via social media. Hala has also set up air raid sirens that Sentry can activate remotely. The warning system now gives people an average of eight minutes to seek shelter.

5__Using a neural network, an automated system continuously scans Facebook, Twitter, and Telegram for posts that might indicate air strikes.

Precision was essential, Murad says. If Sentry went live too early and was inaccurate, civilians wouldn't trust it, and it would fail to catch on. But Murad was eager to get it out there. Every day it was in development was another day people could be dying. At this point, part of his job was to watch videos of air strikes and look for eyewitness accounts on social media and in news reports to verify the information they received from people on the ground. Day after day, from Hala's office, he monitored the aftermath of the strikes—the dead, the wounded and the dying, the bodies, the blood, and the maimed limbs. "You cannot stop crying, you can't stop yourself," he says, "and you can't get used to it."

Even though the Hala team was still getting by on scant funding, they managed to hire three more Syrians to help Murad look at the video and social media evidence and match it against Sentry's predictions. But it took hours to verify the trajectory of a specific plane from air base to bombing site. And some days there were dozens of strikes. The new staffers couldn't keep up. So the team figured they needed to automate the process. Jaeger hired engineers and researchers to develop software that, with the help of a neural network, could search Arabic language media for keywords that would help confirm the location and timing of an air strike. More data on more air strikes meant better information and better predictions.

As they were working to get accurate data, they also needed a way to get the warnings out to civilians. Murad wrote scripts for Telegram, Facebook, and Twitter, as well as the walkie-talkie app Zello.

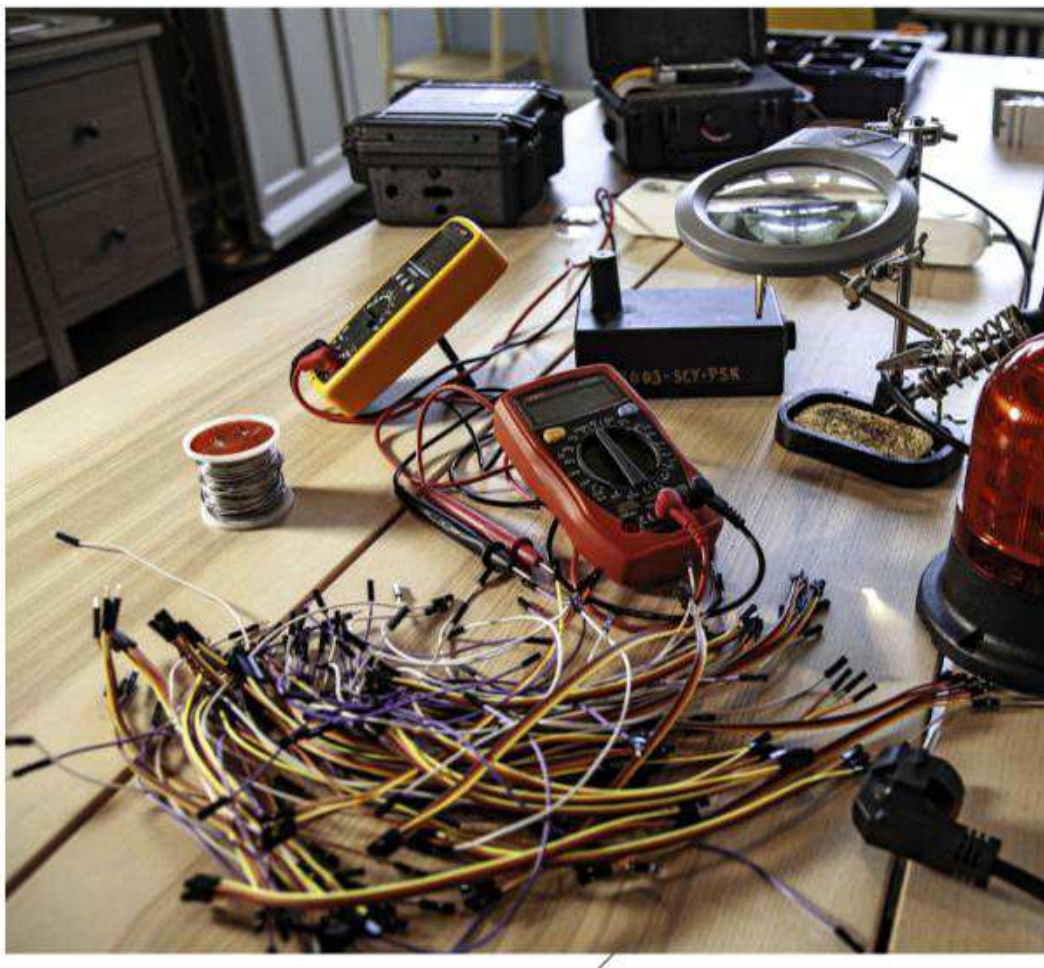
On August 1, 2016, Sentry was ready to go live. The team started small, launching it in part of Idlib Province, which was getting hit hard by air strikes. They reached out to Syrian contacts and shared the news on social media. Volunteers passed out flyers. "Within a day and a half," Jaeger says, "we got a testimonial video from someone who said, 'My family is alive because I logged in and I got this message and I moved from my house. The house got blown up, my neighbors got killed.'"

He showed me the video, sent to him by someone in Syria. In it, a young man, visibly shaken and standing near a pile of rubble, confirms what happened. When Jaeger first saw it, he cried. "It was the first time we actually realized what we had done," he says. "One family being saved. It was all worth it." After that, no one was going to take a break. Levin remembers putting in 90- and 100-hour workweeks. Murad once toiled for three days straight without sleep.

All those hours led to a number of important improvements. Take the warnings. They need to reach as many people as possible, even those without access to cell phones, computers, or radios. Some areas in Syria already had air raid sirens, but they had to be manually activated. That meant running across town. "You're bleeding off minutes at that point," Jaeger says. So Hala modified a siren by adding a component that would let Sentry activate it remotely. The team shipped prototypes, each about the size of a cigarette carton, to the White Helmets, who helped test the units by placing them in civil defense bases and hospitals. There are now as many as 150 of these sirens inside the country, and Hala is figuring out how to make them work even during power and internet outages.

The latest addition to Sentry is a sensor module that's designed to distinguish between airplanes, and gauge speed and direction. Every sound has a unique signature, whether it's a reggae song, a human voice, or the roar of a warplane. To capture the signatures they needed to train Sentry's sensors, Jaeger's team used open source data and field recordings of Syrian and Russian jets. According to Hala, at optimal range Sentry can now identify threatening aircraft about 95 percent of the time.

Jaeger is cagey about how many of Hala's sensor modules are deployed in Syria, but he says they've been operational since March. People have placed the briefcase-sized units on rooftops in opposition-held areas, giving clear access to the sound signatures of government warplanes overhead. The modules are still in development but have been made entirely from cheap, off-the-shelf technology. "Ten years ago this was impossible," Jaeger says, "especially at such a low cost." What Hala has done, essentially, is give Syrian civilians a radar system—and a better chance of surviving against overwhelming and indiscriminate force.



TESTING GEAR IN HALA'S OFFICE

“WE CAN NOW LINK BOMBINGS AND HUMAN CASUALTIES AND ALL THESE WAR CRIMES TO AN AIRPLANE, TO A PILOT, TO AN AIR BASE, TO AN AIR WING, TO A COMMANDER.”

In a five-story walk-up, Jaeger, Murad, and Levin work out of a three-bedroom apartment that has served as Hala’s headquarters since October 2017. Perched on couches, they could pass for cofounders of any startup. A very basic startup: There are a few laptops lying around and not much else. Most coordination with the company’s now 18 employees is done over Slack—many work in cities like London and Washington, DC. Jaeger is fond of mentioning the PhD engineers, researchers, and data scientists he has on his meager payroll.

The company is currently surviving off the initial investment, grants and contributions from the UK, Denmark, US, and Canadian governments, and a small round of funding from friends, family, and a couple of other investors.

As we talk, Murad pulls out his cell phone. A warning has come in: A Russian warplane is circling Jisr al-Shughur, an opposition-held city. Within a minute, Sentry reports it has activated a siren. Minutes later, Murad pulls up a tweet from a Syrian account confirming that an air strike has hit the city. Hala’s data shows that about 11 minutes elapsed between the siren and the bombing. Later analysis showed no deaths or injuries.

Everything about Sentry hinges on a simple fact: The more time someone has to prepare for an air strike, the greater their chance of survival. And now lots of people are relying on Sentry for that edge: 60,000 follow the Facebook page. Its Telegram channels have 16,400 subscribers. A local radio station broadcasts Sentry alerts. And there are all the people within range of the sirens. In surveys conducted in Syria, Hala found that people need a minimum of 1 minute to seek adequate shelter. Had Abu al-Nour not had time to gather his children, they certainly would have been injured or possibly killed. A few seconds more would have kept his wife from injury. Jaeger says Sentry now averages a warning time of eight minutes.

The team knows they have saved lives. But they also did something they hadn’t foreseen: gathered a critical set of data. “We believe we have the most complete picture of the air war in Syria outside of the classified environment,” Jaeger says. That data is invaluable for groups trying to address human rights issues and war crimes. Hala has already made data available to the UN. “From a prosecution perspective, it’s invaluable,” says Tobias Schneider, a research fellow at the Global Public Policy Institute who studies chemical weapons and war crimes in Syria. “We can now link bombardments and human casualties and all these war crimes; we can connect them to an airplane, which means we can connect them to a pilot, we can connect them to an air base, to an air wing, to a commander.”

An official involved in investigating war crimes at an international human rights organization says Hala has played a key role in identifying the perpetrators of attacks on targets like schools and hospitals: “They have laid the groundwork for the attribution of human rights violations to specific parties and, ultimately, for their accountability.”

Jaeger imagines other valuable applications for Hala’s technology, often to monitor hard-to-govern spaces. It could track poachers in Kenya or help poor countries with border security. Essentially, he says, the tech could be useful wherever sound signatures—gunfire, vehicles—can help monitor wrongdoing. It’s like a mash-up of ShotSpotter’s sensor capabilities and Palantir’s data analytics, but aimed at markets that neither of those companies would likely find lucrative enough.

Of course, it could also be used for other, less beneficent, purposes. One need not look far in the tech sector to find products intended to do good that instead cause a lot of harm. Sure, Sentry could be used to stop poaching or track Boko Haram, but could poachers use similar tech to locate elephants, or could a dictator use it to monitor activists? How do you stop it from getting into the hands of bad actors, from being repurposed to target the very people it was designed to protect? What if the Assad regime figures out how to hack Sentry?

Jaegar acknowledges the potential for misuse. Hala is a for-profit business that wants to offer its services to public and private entities and license its tech to other companies. There’s no telling who might be interested in it and how big an offer might be. Jaeger says that Hala will be picky about its clients. Every technology has many uses, he adds. The team’s only goal is to save lives, he says, and he’s confident they can uphold their mission: “We’re not making things that are inherently dangerous. We’re not making weapons.”

After al-Nour’s home was bombed, he and his family salvaged what they could and relocated to a not-too-distant town. Air strikes followed not long after. They fled to a camp for displaced people. When the conditions there became unbearable, they moved to a house near their home village. Al-Nour has tried to find work in factories but hasn’t had any luck. For a while he thought he’d never go back to his home. His children were terrified to return, and he feels a sort of hatred toward it. But he was spending so much of what little money his family had on rent that he decided to restore the ruined structure. He now spends his days trying to erase traces of the bombs that shattered their lives.

WHAT HAPPENED IN THE DARK

BY DANIEL ALARCÓN

PHOTOGRAPHS BY ROSE MARIE CROMWELL

PUERTO RICO´S YEAR OF FIGHTING FOR POWER.

JORGE BRACERO

SEVERAL WEEKS BEFORE he would become a folk hero across Puerto Rico, Jorge Bracero slipped in a puddle at San Juan's central power plant and broke his leg.

After a few days in a cast, he began to feel pain so intense he was unable to sleep or eat. When doctors realized he had developed blood clots in his injured limb, they prescribed a six-month regimen of blood thinners and barred him from returning to work for the duration.

It was July 2017. So when the first big storms of that hurricane season began bearing down on Puerto Rico, Bracero—a power plant operator with the island's public electric power authority, known as Prepa—sat on the sidelines, miserable and frustrated, reliant on a pair of crutches.

Bracero is 38 years old and stoutly built, with buzzed hair and a dark beard. He has a sharp, pointed nose and prominent eyebrows that sometimes knit up into twin, back-to-back apostrophes at the middle of his forehead—especially when he is concerned. And he was often concerned that fall.

When Hurricane Irma hit the island on September 5, Bracero and his wife, Charlot, were among the 1.1 million Puerto Rican customers who lost power. They rode out the storm and its aftermath with relatives who had a generator; Charlot was seven months pregnant with their first child. Bracero slept on a couch, passing his days laid up in the humid late-summer heat, anxious that his wife might go into early labor, and fuming that he couldn't do his part to get the power back on. "I felt useless," Bracero says.

The job that Bracero was desperate to get back to can be brutal on a good day. On any given shift, he and one or two partners are responsible for operating two 15-story-high boilers, along with the 20 burners that heat them to produce steam and the six massive power-generating turbines that turn under the steam's pressure. Bracero's role is to tend to the machinery itself, while his partner sits at a console monitoring the plant's water, oil, temperature, and pressure levels, constantly relaying information to Bracero. The heat is intense, the work exhausting. When he comes home, his clothes go straight to the balcony because they smell so powerfully of sweat and diesel.

Since he was unable to pitch in at the plant, Bracero settled instead for defending his colleagues on Facebook, where predictable rounds of invective were being heaped on Prepa for its failure to restore power. Normally, Bracero's Facebook persona tended toward cheeky political memes, *Game of Thrones* jokes, and *Star Wars* references. But now he took to posting photos of Prepa workers doing dangerous things to get the lights back on. One grainy cell phone image showed a lineman balancing on a helicopter skid in midair, stretching his arms out into space to repair wires at the tip of a utility pole. "And then they yell, GET MOVING," Bracero wrote. After Irma raked across Florida, he shared a video that someone had taken from high above a field near Jacksonville; the camera slowly panned across a sea of white bucket trucks that had assembled from all across the United States. "That's why Florida has light and we don't. That's 16,000" workers, he wrote. "Here we are alone."

Hurricane Maria hit Puerto Rico just two weeks after Irma. "I have a very apocalyptic mind," Bracero says, but the storm's ferocity was nonetheless beyond what he could imagine. It brought sustained winds of 155 miles per hour and a 9-foot storm surge, cutting a roughly diagonal line across the island from the southeast over a span of nearly eight hours; its trajectory felt almost deliberate, as if plotted out to inflict the most damage. Bracero compared it to a terrorist attack. Eighty percent of Puerto Rico's electrical transmission lines went down. The entire island lost power.

Bracero couldn't stand being idle anymore. After the storm, several employees of the San Juan power plant were unaccounted for. No one knew when, or if, they would return to work. Without hands on deck, Prepa was never going to get the lights back on. So Bracero pressured his doctor to sign a medical release. Of course, if you're taking a blood thinner, a cut can be catastrophic, so the doctor agreed on the condition that Bracero wear an extra pair of gloves, an extra long-sleeve shirt, and a pair of spandex pants underneath his work clothes. When he looked in the mirror wearing this new uniform, Bracero laughed. In the boiling heart of a power plant the temperatures routinely soar above 100 degrees Fahrenheit, but he was dressed as if he was going skiing.

Once he was back at Prepa, Bracero quickly came to understand the magnitude of the damage. But his head was also still stuck in social media, which—like all media after the storm—was maddening to him. News coverage appeared to be designed to spread panic. "My wife and family were watching me yell at the television," he says. Nor was Prepa doing a particularly effective job of communicating. So Bracero made another drastic move: "I decided to become a news outlet myself."

He started using his Facebook page to post daily updates on the effort to repair the grid. Favoring extreme transparency, he posted raw screenshots of the spreadsheets listing the work assignments of every power and light brigade on the island, alongside frank attempts to explain how the grid works and what it would take to get each part of it up and running. One day, when a steam turbine at a major power plant failed, he dug up an animated video about how steam turbines work. He warned that the clip was "ASTRONOMICALLY BORING" but pointed people to the five-minute mark if they wanted to get a visual sense of the component that was broken.

Toward the end of each post, Bracero would switch gears and offer a kind of running pep talk; he developed a voice that was simultaneously gentle, urgent, and reassuring, completely free of cynicism or panic. In practically every update, he implored his readers to post videos as soon as their lights came back on. "Tomorrow help others cook, help those who have no light to feel a gift of normalcy," he wrote to people who were about to regain power. "Help wash clothes, help cook. Make Ice!" He'd vary the message slightly, so it didn't seem like boilerplate. "In the dark we have met again as neighbors. Don't forget," he wrote. "Don't go back to your bubble." To people whose pleas for help flooded his comments, he said: "The moment will come. You are not forgotten." When people did post images of their lights finally on, and photos of their freezers full of all the ice they had made for their neighbors, his response was unfailingly earnest. "I'm proud of you!" he wrote, again and again.

By publicly sharing inside information from Prepa, Bracero knew he was taking a risk—he was afraid he might lose his job—but he

▲
A FAMILY ON THE OUTSKIRTS OF BAYAMÓN. HURRICANE MARIA SCOURED MUCH OF THE PAINT OFF THEIR HOUSE, AND THEY WERE STILL WITHOUT POWER IN APRIL.

did it anyway. "If I get fired, it's for doing what's right," he thought. By November, he had to switch over from his personal Facebook page to posting as a public figure on a fan page, because he was overwhelmed by posts, tags, and messages. Within a day, his new page had more than 12,000 followers. Someone made a portrait of Bracero in the style of Shepard Fairey's famous image of Barack Obama—an ersatz block print of Bracero with his long beard and hard hat, an enormous smile on his face—and this became his public profile picture. People sometimes stopped him in the street to thank him, to give him a hug.

In private, however, Bracero was frightened. Now that he was in contact with thousands of Puerto Ricans, he could feel how fragile they were—how fragile the whole island was—after the storm. "I wasn't expecting this level of desperation," he told me. "It scares the shit out of me."

ALL ACROSS PUERTO RICO

over the past year, people like Bracero have taken matters into their own hands in ways that are both inspiring and distressing.

When it became clear to Javier Jiménez, the mayor of a northwestern town called San Sebastián, that power wasn't going to be restored right away after Maria, he decided to go rogue. He gathered a handful of brave (some might say *reckless*) city workers, along with a few retired Prepa employees willing to volunteer, and mobilized them to reconnect the 40,000-person town to the grid themselves. It was inordinately dangerous, but Jiménez felt that the greater risk was inaction. San Sebastián is about two hours from the capital, San Juan, and for many residents, particularly the elderly and the infirm, having electricity was a matter of life and death. "It was a state of emergency," the mayor told me. "Nobody could've stood in my way. Not Prepa. Not the governor. Not the president of the United States."

Jiménez called his band of vigilante line workers the PPA—the Pepino Power Authority—after the surrounding Pepino mountains. The PPA asked men and women in San Sebastián to come out with their own machetes to prune back the brush and tree limbs, helping clear a path to fallen

poles near their homes. Then the PPA's core team of volunteers would step in, repairing poles, scavenging parts, and running new cable. Officially, Prepa was not pleased to have a local amateur utility reconnecting high-voltage power lines. Unofficially, Prepa employees were slipping spare parts to the renegade municipal power crew, one volunteer told me, to help speed up the reelectrification.

In another town, Adjuntas, nestled in the mountains about an hour and a half southwest of San Juan, an NGO dedicated in part to solar power, called Casa Pueblo, became a pillar of the local recovery. When the town's 18,000 residents were cut off from the rest of the island after Maria, the NGO's solar-powered radio helped authorities find out which roads were clear and which families were in danger, and attend to emergencies when the central government and federal authorities were not yet responding. Casa Pueblo subsequently gave out some 14,000 solar-powered lamps and also offered a solar-charged satellite phone at its offices for locals to use. At any given time, five to 10 people waited to make a call.

Arturo Massol, the associate director of Casa Pueblo and an ardent evangelist for decentralized, renewable energy, described what was happening on the island as "an energy insurrection." Ordinary Puerto Ricans, he said, had woken up to the fact that when it came to electricity, they would have to look for alternatives.

On the mainland, green-tech commentators pointed to Maria as an opportunity to turn the island into a laboratory for experimenting with microgrids, renewables, and climate-resilient infrastructure. Two weeks after the storm, a Twitter user in Virginia named Scott Stapf issued a hypothetical challenge: "Could @elonmusk go in and rebuild Puerto Rico's electricity system with independent solar & battery systems?" Musk replied with characteristic bravado: "The Tesla team has done this for many smaller islands around the world, but there is no scalability limit, so it can be done for Puerto Rico too." Puerto Rico's governor, Ricardo Rosselló, tweeted back: "Let's talk."

But as they waited for the lights to come on, the vast majority of Puerto Ricans found alternatives to the grid in the most obvious, least sustainable places. Diesel and gas generators became the island's constant, deafening background noise. Long orange extension cords slithered out of windows, connecting houses to one another, as neighbors shared the power their generators were producing. (One of Bracero's constant refrains on Facebook was a set of pleading instructions on how to power multiple houses using one generator without hurting anyone.) During its busiest period after the storm, one store in San Juan was selling about 400 generators a day.

In the town of Río Grande, less than an hour east of San Juan, the Puerto Rican journalist Ana Teresa Toro told me the hurricane had forced her to rethink the viability of the island itself. "You can't trust the infrastructure anymore," she said. Barely anyone she knew had stayed at their normal weight after the storm: Without consistent refrigeration, people either ate processed food and put on pounds or they suffered through shortages and depression and lost weight. Toro told me some of her friends joked darkly about the thrilling results of this diet.

Heroic improvisation and gallows humor can only get a population of 3.3 million people so far. Electricity is, of course, the utility upon which modernity rests. Without it, there can be nothing approaching normalcy. And the crippling cost of keeping generators fueled just underlined how essential grid power was. Solar power, meanwhile, was uneven without powerful battery backups—and while the number of such batteries on the island was growing, thanks to companies like Tesla, there were still hardly enough to make a dent in demand (see "Balloons, Batteries, and the Crypto Invasion"). Yes, Prepa was a basket case—dysfunctional, archaic, overwhelmingly reliant on imported oil—but it was still palpably and undeniably Puerto Rico's most critical infrastructure. However little people trusted it, there were very few ways around relying on it.

As the post-Maria period moved past its feverish first few weeks, electrical power inevitably became the simplest way of measuring progress toward recovery. And Bracero became one of the most trusted voices on technical questions that had come to feel like existential ones. *How many people are connected now? What percentage of the population? When is the 50900 transmission line going to be operative again*? The bigger question was not so much whether the crisis would lead to a new model for climate resilience, but whether the existing system would even be up and running by the next hurricane season. Doing so would require repairing far more than the damage caused by a single storm in September 2017.

"TOMORROW HELP OTHERS COOK, HELP THOSE WHO HAVE NO LIGHT TO FEEL A GIFT OF NORMALCY," BRACERO WROTE "TO PEOPLE WHO HAD REGAINED POWER. HELP WASH CLOTHES, HELP COOK. MAKE ICE!"

WHEN JORGE BRACERO began working for Prepa back in 2005, it was an institution that commanded some respect. By some measures, Prepa was (and still is) the largest public electric utility in the US, serving more customers than the Los Angeles Department of Water and Power or the Long Island Power Authority. Its grid, splayed across the rugged landscape of Puerto Rico, had been instrumental in the island's economic development. Its finances were sound. "I chose to be a blue-collar worker," Bracero recalls.

But as it happened, 2005 was also around the time when Puerto Rico's entire economy began a long, as yet unchecked slide, taking Prepa with it. The causes of the collapse were no mystery. For decades, federal tax law had offered US corporations major exemptions if they set up shop in Puerto Rico. Waves of this tax-incentivized industrialization had brought petrochemical plants, and then pharmaceutical and tech companies, to the island. But by 2006 the last of those tax breaks were phased out, and an exodus of Puerto Rico's industrial employers began in earnest. The island's GDP per capita fell in tandem. Unemployment spiked. Between 2000 and 2015, as economic stagnation took hold, nearly 10 percent of the population, mostly working-age Puerto Ricans, left for the mainland.

The island's tax base became a hopelessly moving target. From 2002 to 2014, the Puerto Rican government overestimated its revenue eight times, on one occasion by as much as 19 percent. Deficits grew year after year. To cover costs, Puerto Rico began to borrow heavily, issuing bonds to close budgetary gaps in ways that might be charitably described as creative. And they were easy to sell, in part because of another quirk in the US tax code: Earnings on Puerto Rican bonds were triply exempt from state, federal, and the island's own territorial taxes. Investment banks, retirement funds, and individual investors from the island and the mainland bought billions of dollars' worth, helping to prop up what amounted to a fiscal Ponzi scheme. By 2015 the situation was untenable, and then-governor Alejandro García Padilla declared that Puerto Rico's $72 billion in debts were not payable, setting into motion a series of negotiations with bondholders that culminated in an unelected oversight board taking control of the island's finances.

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BALLOONS, BATTERIES, AND THE CRYPTO INVASION

WHAT TECH HAS DONE FOR PUERTO RICO.

BY NICK STOCKTON

Two weeks after Hurricane Maria, Donald Trump flew to Puerto Rico, toured a relatively affluent neighborhood there, and expressed his relief that the storm had not been "a real catastrophe" like Hurricane Katrina. He jokingly chided Puerto Ricans for throwing the federal budget a "little out of whack." In reality, Maria caused the largest blackout in US history, and the federal disaster response on the island was, at that point, a fraction of what residents of Florida and Texas had received during the same hurricane season. According to *The New England Journal of Medicine*, the storm and its aftermath ultimately killed more than 4,000 people.

If the federal government's response to Maria was a scandal, the tech industry's initial reaction seemed, comparatively, like a source of hope. In the days after the disaster, a small groundswell of private tech enthusiasm furthered the notion that Puerto Rico ought to become a test bed for renewable, distributed, climate-resilient infrastructure. Companies like Alphabet and Tesla, which were already working on the island, looked like they might be poised to make this idea a reality. Later, a different set of tech entrepreneurs descended on Puerto Rico as well, enticed by tax breaks to advance other, more esoteric techno-utopian visions. Here's a progress report on how tech has, and hasn't, managed to come to Puerto Rico's rescue.

ALPHABET

For years, Alphabet's X (formerly known as Google X) has been working on a project called Loon, which provides cell service to remote areas via giant balloons. And it just so happened that one of the company's two launch facilities for those signal-slinging balloons was located in Ceiba, on Puerto Rico's eastern coast. So the company deployed a handful of the floating antennas, blanketing the island with text and data service for more than 250,000 customers of T-Mobile and AT&T for four months while parts of the electrical grid were down.

TESLA

Two weeks after the storm, Elon Musk wrote on Twitter that Tesla had a track record of building decentralized electrical infrastructure—independent solar and battery systems—on small islands. "There is no scalability limit, so it can be done for Puerto Rico too," he said. Puerto Rico's governor, Ricardo Rosselló, tweeted back: "Let's talk." Since then, updates have come mostly in the form of more tweets. In April, Musk reported that "Tesla batteries are currently live & delivering power at 662 locations in Puerto Rico." Then in June he tweeted, "We have about 11,000 projects underway" on the island. Tesla has declined to clarify what that means or how many Puerto Ricans are served by those projects.

THE BLOCKCHAIN CROWD

Over the past year, about 150 cryptocurrency entrepreneurs have settled on the island, according to Giovanni Mendez, a tax lawyer who has helped many of them. They've been drawn in part by incentives, passed in 2012, that give tax exemptions for capital gains and passive income to individuals who spend at least half their year on the island, and by an amendment, passed just months before Hurricane Maria, that eased requirements on US companies to hire Puerto Rican residents. One of the new arrivals was the cryptocurrency guru and former child actor Brock Pierce, who promptly said he was setting out to build a utopian community—perhaps even a whole new city—on the island, to the ire of many Puerto Ricans.

Since then, to pay off creditors, Puerto Ricans have borne draconian cuts in education, public transportation, health, and utilities. As the most economically mobile Puerto Ricans have fled the island, these cuts have fallen on a population that is older, poorer, more isolated—and angrier—than ever. May Day protests in the past two years have turned violent.

The years of austerity and economic contraction took a particularly harsh toll on Prepa. In 2016 a report ordered by the regulatory body in charge of overseeing Prepa laid bare the utility's sorry state with grim clarity: "Prepa's generation, transmission, and distribution systems are falling apart," it said. Prepa's electrical service had cost more than other US utilities, yet its customer interruption rates were four or five times higher. As a result of "historically thin budgets," Prepa had adopted a self-defeating policy of postponing maintenance and extending outages to avoid paying overtime to its employees. Blackouts had become more frequent, the report said, while the rate of worker injuries and fatalities in Prepa's shrinking workforce was "alarming."

Some of the utility's challenges were a legacy of Puerto Rico's industrial past. The island's largest power plants had been built on its less populated southern coast, to serve a now mothballed set of massive petrochemical plants nearby. Now those power facilities were primarily responsible for supplying electricity to the major population centers some 50 miles away on the island's northern coast, via transmission lines that had to cross a rugged, heavily jungled mountain range. Maintaining those lines was an extraordinary task even in the best of times.

The utility was, according to the report's authors, stuck in a vicious cycle: The precarious state of the grid, which lurched from outage to outage, precluded the kind of massive, visionary investments needed to shore up or renovate the system. Not that Prepa's leadership seemed much inclined toward vision. Prepa administrators were alleged to have participated in a fraudulent scheme to accept kickbacks in exchange for buying low-quality fuel oil at inflated prices. A 2016 report from a special investigative committee of the Puerto Rican Senate found that labs working for Prepa had manipulated tests of sulfur content in its fuel to cover the utility's tracks. The scheme is alleged to have involved billions of dollars' worth of contracts. (A class action filed on behalf of customers is still pending.) On top of it all, the utility was more than $9 billion in debt.

Well before the apocalyptic 2017 hurricane season, one thing had been made very clear to all Puerto Ricans: It didn't take a hurricane to knock out Prepa's grid. On the afternoon of September 21, 2016, almost exactly a year before Maria made landfall, a single power switch overheated at the island's largest power plant, causing a cascading blackout that snuffed out the lights for 1.5 million customers. As if to underline the system's fragility, all of this happened under clear skies.

BY DECEMBER 2017, SAN Juan felt half-empty, permeated by the rumble of generators and the sharp smell of diesel. Puerto Ricans had been leaving for the mainland by the thousands each week. It was common to find wreckage that had yet to be cleared; at major intersections, one side of the street might be lit up and the other still dim—a *bolsillo*, or pocket, of darkness. The pattern of illumination followed no discernible logic.

According to best estimates, roughly half of Puerto Ricans were still living without power. A sketch comedy troupe called Teatro Breve was putting on five sold-out shows a week in San Juan, all about living without power, waiting in lines for no reason, and the myriad daily indignities that made up the post-hurricane ennui. The crowd's laughter was deep and guttural, almost pained. In one scene, an actor berated her skeptical husband: "The lights aren't going out today. Jorge Bracero said so!"

Outside, on the streets, there were work crews everywhere—line workers from Prepa and from Florida, New York, and Texas in bucket trucks. The Army Corps of Engineers was also on the scene, but federal rules prevented them from upgrading Prepa's grid. They had to "replace in kind": A wooden electrical pole felled by Maria had to be replaced by another wooden pole, even if a metal one might better withstand the next storm.

Ordinary Prepa employees I spoke to approached their work with a sense of pride and resignation. I spent an afternoon with one brigade of Prepa line workers doing repairs near the city of Bayamón. Raul Lebrón, a grizzled 21-year veteran of the utility, showed me parts he and his coworkers had scavenged from fallen transmission lines, cleaned up, and were now set to reuse. He held a brown porcelain insulator in his hand and estimated it was around 60 years old. The ingenuity of Prepa's line workers astonished their colleagues from the mainland. Johnny Price, a Con Edison manager from New York who oversees line workers, spent six weeks in Puerto Rico that winter and told me he'd never seen work like this before. "They see a pole, they stop, strip it, use what they can. They would reach into oil-filled transformers and start rewiring on the fly. They do calculations in their head. It was pretty impressive."

But no one could be impressed by the overall slow pace of recovery. In January, Governor Rosselló made an announcement. "The Puerto Rico Electric Power Authority has become a heavy burden on our people, who are now hostage to its poor service and high cost," he said. He announced his intention to privatize Prepa and sell off its assets, and signaled that he intended to move fast.

BY SPRING, THE NUMBER of customers for whom power had been restored in Puerto Rico had climbed past 1.4 million, but it could lurch down again in an instant. On February 11, an explosion at the Monacillos power plant plunged the capital back into darkness. A few weeks later, in early March, blackouts hit San Juan once more, two days in a row. On April 12, a tree fell along one of the island's electrical transmission lines near Salinas, knocking out power to nearly 1 million people. Six days later, a contractor hit a line with an excavator and the island went dark once more.

"As soon as the lights go out, my phone blows up," Bracero told me in April. "People are traumatized." He was as busy as ever at work, recovered from his injuries, and posting all the time. During the second blackout that month, one of Bracero's updates was shared more than 4,000 times and gathered hundreds of comments. The thread included conspiracy theories about the privatization effort, speculating that the outages were part of a plan to further delegitimize the

utility, paving the way for Rosselló's deal. All day long, Bracero provided updates, trying to maintain the same tone of serenity he had been using since the hurricane.

That month, I went to see Francisco Rullán, the official appointed by Governor Rosselló to direct public energy policy and help oversee the government's privatization plans for Prepa. His office sits in what is known as La Milla de Oro, San Juan's Golden Mile, the city's financial center. There isn't much that's golden about it anymore, the disrepair and blight that preceded the storm apparent even here in boarded-up windows and half-empty office buildings. A modest gathering of former teachers stood in front of the building, protesting cuts to their pensions and school closures, posing for pictures in front of their homemade signs, and handing out flyers to passersby.

Before assuming his current role, Rullán had worked as an engineer at Prepa for more than two decades, so he knew the utility from the inside and was keenly aware of both its assets and its shortcomings. But Prepa's inability to fulfill its mission of providing consistent electricity to Puerto Rico was, no matter how you looked at it, a scandal. It was, after all, an inefficient state monopoly that lost money despite its captive customer base. "My entire family still has no power," he told me, just moments after we'd sat down. He was referring to his parents, who lived in a town called Utuado, in the island's mountainous center. "I always use them as an example. Going without power has become normal." He encouraged me to visit them so I could see for myself.

The first step in the privatization plan, Rullán told me, was to get Puerto Rico's legislative assembly to change the law to allow Prepa to sell its assets. The next step would be to get buyers lined up—either for the entire utility or for different elements of Prepa's broad portfolio: its aging plants, tens of thousands of miles of power lines, irrigation systems, right-of-way easements, and fiber-optic cable, to say nothing of its contracts with thousands of employees and its considerable debt.

The new Prepa, he assured me, would offer lower prices for the consumer, more options, 50 percent renewable fuel sources by 2040, microgrids, and more. But many observers were skeptical. Rosselló's proposed bill to privatize Prepa had explicitly blocked the utility's regulator, the Puerto Rico Energy Commission, from overseeing the sale of private contracts. The plan instead stipulated that Prepa's seven-member governing board would run the 18-month-long process. The credit-rating agency Moody's called the timeline "quite aggressive."

Cathy Kunkel, of the Institute for Energy Economics and Financial Analysis, worried that privatization without regulatory oversight would just open up opportunities for corrupt, politically driven business deals. Prepa's leaders, after all, had already been accused of taking kickbacks and making bad deals for their customers, as with the fuel oil scandal. And the fact remained that Prepa was the largest single public asset in all of Puerto Rico—the biggest thing the territory had left to sell off. What terms might a buyer demand to purchase a creaking electrical system that provides power to a shrinking customer base on an island sure to be hit by more storms and hurricanes? In a report that Kunkel helped author, the IEEFA was particularly dubious that a new private owner, absent robust regulation, would voluntarily shift toward renewable fuel sources: Why would you pave the way for distributed forms of energy generation, like solar, when they compete with the centralized power grid you've just bought?

PREPA LINE WORKERS RETURN POWER TO A HOME IN PUERTO RICO. ▼

I asked Rullán what the model was for a wholesale transformation of a public utility like the one he was proposing. He shook his head; Puerto Rico would *be* the model. His tone wasn't boastful; it was optimistic in a way that felt surprising, given the context. "What we do here will make history," he said.

José Roman, then the interim president of the Puerto Rico Energy Commission, the sidelined regulatory body overseeing Prepa, was less optimistic. He wasn't opposed to privatization in principle, but he had little faith in the process that had been set in motion. Privatized energy markets have to be designed carefully: Supply and demand must always be in balance, or the entire system fails. He feared that the sale would become yet another missed opportunity for the Puerto Rican consumer. "Yes," he told me. "We will be studied. We'll be studied for everything we did wrong."

DURING MY FINAL TRIP TO Puerto Rico in April, I decided to visit Utuado, the town where Rullán had said his family was still living without power. Along the road there, I ran into two men picking up telephone wire that had been knocked down by the storm. Michael Casiano and Carmelo Fuentes were cutting the cable they had gathered into meter-long lengths, stacking the pieces in the bed of their beat-up truck, and then bringing it to someone from the phone company, they told me. They seemed happy to have a job.

Casiano was tall and thin, wearing dark glasses. He had a broad, friendly smile. Fuentes was heavyset and strong, with thick arms and giant hands. Fuentes told me he'd almost lost his mind after Maria, and though I barely pressed him, it soon became clear he wasn't speaking in metaphor. His family had had no water and never managed to buy a generator. Everything seemed hopeless. One of Fuentes' neighbors, a 22-year-old woman, had hung herself. The young woman's mother and brother had followed suit, though both survived. I asked Fuentes how he knew he was having mental troubles. "Because I was arrested," he told me. He woke up in a straitjacket. But he was better now. He smiled bravely, as if to prove it.

Casiano wanted to agree but instead offered: "Puerto Rico can't withstand another one of these."

Along the way to Utuado, the roads narrow and snake. These sparsely populated towns up in the hills, where the brush is thick and the trees curve over the roads, may well be the last places where power is restored. If another massive storm comes, residents worry they'll find themselves once more at the back of the line.

Rullán's parents met me halfway up the hill, and we drove up together toward a small nursing home called Ciudad Dorada, Madre de Dios, which was still operating without grid power. Its director, Luz Collazo, told me she couldn't afford to use her generator much; she was spending around $300 a

◀ LEFT: A SHOWER THAT HAS BEEN RIGGED TO WORK WITHOUT ELECTRICAL PUMPS AT A NURSING HOME RUN BY LUZ COLLAZO, RIGHT. THE FACILITY WENT WITHOUT GRID POWER FOR NINE MONTHS.

week on diesel. She had invested thousands of dollars in solar panels, but the building was too large for them to power it all at once. A visitor staying in the home had died a few weeks after Maria. Two of Collazo's 10 residents needed oxygen, more than half had Alzheimer's, and all but one were over 80 years old. For hot showers, Collazo and her husband, Miguel, warmed water on the stove. They also gathered rainwater in a large plastic kiddie pool on the roof.

Collazo took me out to the terrace, looking over a lush valley. "No one's come to pick up the power lines," she said. "No one's even come to survey the damage." What was most maddening was that the vast majority of the utility poles along the road to the nursing home had survived. In all, Collazo's nursing home would go without grid power for nine months.

By the spring, one piece of good news had arrived from Washington: The new congressional budget allowed for an exception to the usual rules of federal disaster funding, and now FEMA could pay for major upgrades and new designs for Prepa's grid. But that exception was only guaranteed to apply as long as the utility stayed public. Nevertheless, on June 11, the Puerto Rican legislature approved a bill to privatize Prepa. And on June 20, three weeks after the start of the new hurricane season, Governor Rosselló signed it into law.

Exactly one month later, Prepa was in crisis once again. On July 11, the utility's CEO of just four months, a non-Spanish speaker named Walter Higgins, announced his resignation, citing personal reasons. There had been considerable public outcry over his salary, which at $450,000 ranked among the highest of American public electric utility CEOs. The utility's governing board, the same body that Rosselló had hoped would oversee the privatization process, then appointed one of its own members as the new CEO. The new head promptly told a San Juan radio station that the $750,000 he'd accepted to work as director of the beleaguered utility was "a sacrifice." Amid public uproar, the governor asked the board to lower his pay; rather than comply, more than half of the board members resigned in one extraordinary day. By the following week, yet another chief executive had been appointed, the fifth since the storm. In the midst of the shake-up, the governor was on his way to Russia to watch the World Cup soccer finals. Hurricane season was under way, and after the largest blackout in the history of the US, the utility charged with keeping the lights on appeared to be all but leaderless.

For workers like Bracero, this was all demoralizing. When we last spoke, he confessed that he'd expected at some point to be named Prepa's spokesperson, or at least moved to the communications team. But every time he broached the issue, the CEO of Prepa would resign, and Bracero would be back at square one. He still lived an odd double life: at once a public figure and a guy climbing around a power plant in a hard hat, reeking of diesel. He'd been in talks to become an island-wide radio personality, and had in fact been scheduled to go on the air that week. But he'd had to postpone his debut: The San Juan plant was as understaffed as ever, and he had been working double shifts for two weeks straight. "I've been doing this for 13 years," he told me, with weariness in his voice. He wasn't sure how much longer he could keep going before he burned out.

Additional reporting by **NICK STOCKTON.**

COLOPHON

FOREIGN AFFAIRS THAT HELPED GET THIS ISSUE OUT:

Special-ordering mescal; stress-booking a trip to Maui to avoid thinking about Moscow; *Portuguese News* on SBS On Demand; France vs. Croatia; drinking room-temperature ale in a 14th-century pub; finally beating the Mars level in *Beautiful Katamari*; brushing up on my French while planning a vacation in Europe; the Brazilian sci-fi series *3%*; Queen Elizabeth's brooch-based diplomacy during President Trump's visit; doing a *pintxos* crawl in Donostia/San Sebastián; Maria Butina's multitude of glamour shots; surfing with dolphins in Rosarito, Mexico; so much Netflix original anime, including *Devilman Crybaby*; the amazingly good reception (and encryption) I get with voice calls over Signal, whether talking to writers in Ukraine, New York, or Barcelona.

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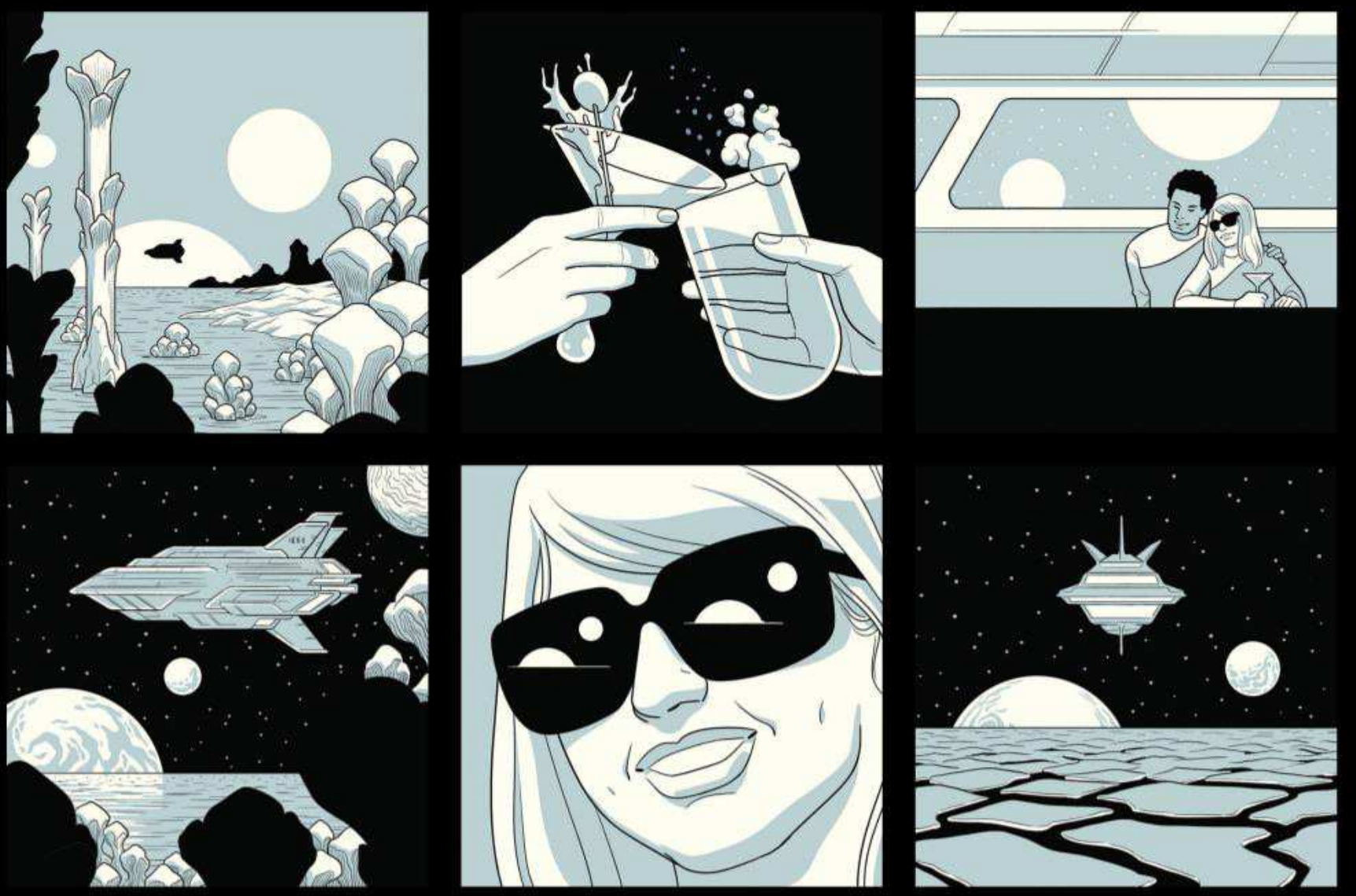

A VACATION DESTINATION BEYOND EARTH:

TRIPLE SUNSET, DOUBLE MARTINI, BLUEST PLANET.

BY @RIINA_STEN, VIA INSTAGRAM

HONORABLE MENTIONS: ENJOY 13,140 HOURS OF IN-FLIGHT ENTERTAINMENT. (JOE BULONE, VIA FACEBOOK) **// POP THE QUESTION ON SATURN'S RING.** (@CHARLIEBRANDON, VIA INSTAGRAM) **// DANCING WITH THE STARS. FOR REAL.** (@THINK0RTHWIM, VIA TWITTER) **// WE WOULD TELEPORT, BUT DAD'S CHEAP.** (@DIMITRI246, VIA INSTAGRAM) **// MARS TRIPADVISOR REVIEW: BORING; NO ATMOSPHERE.** (RICH JEFFERY, VIA FACEBOOK)

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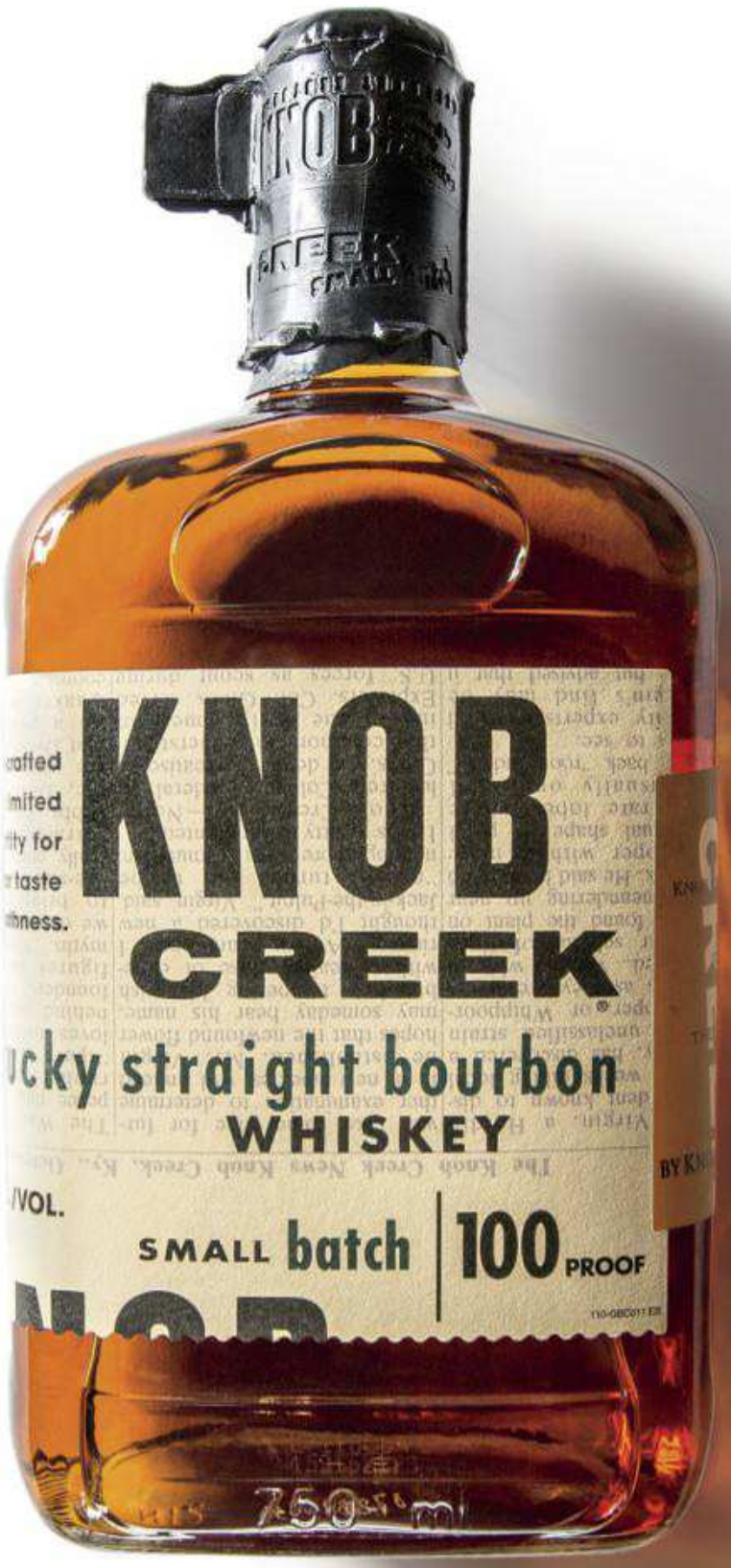

EVERY BIT EARNED